Education and Technology Series

SCHOOLS, COMPUTERS, AND LEARNING PROJECT

Interim Report #2 From the Kingston Regional Pilot Test Centre: Integrating Computers in the Junior Division Curriculum

JOHN OLSON
DONNA POTHAAR

This research project was funded under contract by the Ministry of Education, Ontario.
It reflects the views of the authors and not necessarily those of the Ministry.

Chris Ward, Minister
Bernard J. Shapiro, Deputy Minister

Ministry of Education
Ontario

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CONTENTS

Chapter		Page
	LIST OF TABLES	v
	LIST OF FIGURES	v
	ABSTRACT	vi
	PREFACE	vii
1.	THE RESEARCH STUDY	1
	Purpose	1
	Methodology	4
	The School	12
	The Teachers	12
2.	THE COMPUTER AS A RESOURCE FOR LEARNING	20
	Introduction	20
	The Computer as Resource	20
	Computer-Based Learning Activities	21
	Learning Outcomes	24
	Computers and Student Conceptual Change	37
3.	INTEGRATING THE COMPUTER INTO THE CLASSROOM	46
	Integration with Curriculum	47
	Integration with Classroom Routines	53

Chapter Page

4. SIGNIFICANCE OF THE STUDY: QUESTIONS ABOUT CHANGE .. 61

Making Sense of Practice 61

Computers and the Process of Change 66

REFERENCES 73

APPENDIXES

1. Planning, Designing, and Teaching the Unit 74

2. Research Documents 94

A. Preliminary Teacher Interview Schedules 94

B. Follow-up Teacher Interview Schedule 98

C. Follow-up Student Interview Schedule..... 99

D. Student Worksheets 100

E. List of Project Presentations 106

F. Description of Work in Grade 4 Folders 107

LIST OF TABLES

Table		Page
1.	Grade 4 Fire Unit Plan	8
2.	Grade 5/6 Fire Unit Plan	9
3.	Student Perceptions of the Unit	52

LIST OF FIGURES

Figure		Page
1.	Classroom Layout - Grade 4/5	15
2.	Classroom Layout - Grade 5/6	19

ABSTRACT

In this study we explore two themes: learning from computers, and integrating computers into junior division curriculum and classroom routines.

We worked collaboratively with Grades 4/5 and 5/6 teachers in an elementary school to develop an integrated Social and Environmental Studies unit incorporating the OESS program FLAME LIFE. Fire is a topic which we felt would interest students while allowing important junior division objectives to be pursued.

The unit comprised four elements: science studies of combustion; social studies focusing on historical, cultural, and technological aspects of fire; language arts activities involving reading and creating myths about fire; and mathematics activities involving producing and interpreting line graphs that were based on the experiment and on a computer simulation of the experiment.

We are interested in the contribution software can make in helping children learn basic concepts in science. Computer-based learning may be critical here. If students can explore important systems interactively and be guided to notice key variables and to infer relationships, Computer Assisted Instruction (CAI) can play a role in science learning and concept development.

Teachers have teaching routines which help them solve perennial problems in schooling. The introduction of computers may require new routines and recognition of the goals to which the routines are dedicated. It is especially important to understand the demands of integrated teaching.

PREFACE

This study is an investigation of children's learning and thinking about combustion (as part of a multidisciplinary curriculum unit) in order to understand their conceptions. It also investigates the role the computer can play in helping teachers adapt the learning environment to children's natural ways of learning.

We worked collaboratively with Grades 4/5 and 5/6 teachers in an elementary school to develop an integrated Social and Environmental Studies unit i corporating the OESS program FLAME LIFE.

The study took place in three phases: planning, designing, and teaching the unit. The researchers worked as participant observers in collaboration with the teachers throughout the project. We collected data through observation, interviewing, and document analysis. Data were recorded by audiotaping the planning and design meetings and the interviews with staff and students. We videotaped parts of the teaching phase, and collected and analysed students' work.

Chapter 1 provides background to the study. Chapter 2 examines the computer as a resource for learning, and chapter 3 discusses the integration of computers into curriculum and classroom routines. Chapter 4 explores the interplay between existing classroom routines and the potential of computers to effect change.

Attached to the report is a chronological description of the planning, design, and teaching phases of the SES unit (Appendix 1). The research documents are contained in Appendix 2.

CHAPTER 1: THE RESEARCH STUDY

PURPOSE

(1) Focus of Research

There are two major areas of research in this study of computers and social and environmental studies (SES). They are:

(I) Computers and concept development: We are interested in the contribution software can make in helping children learn basic concepts. There are certain basic concepts in science that students must grasp if they are to begin to understand science as a whole. Unless these concepts are well taught, prospects for widespread scientific literacy are not good. Computer-based learning may be critical here. If students can explore important systems interactively and be guided to notice key variables and infer relationships, Computer Assisted Instruction (CAI) can help in overcoming barriers to science learning. Given the importance of widespread scientific literacy, it is worthwhile to explore the potential of CAI in this area.

(II) Computers and teaching routines: Our purpose is to understand how teachers incorporate software into their teaching routines, and how the software influences teachers' thinking about the subjects they teach. Teachers have ways of teaching--routines--which help them solve perennial problems in schooling. The introduction of computers may require new routines and

recognition of the very goals to which the routines are dedicated, as well as the development of new ways to evaluate student achievement. We have found that pre-existing routines exert a strong influence over how computers are used in schools (Olson and Eaton 1986). It is those routines and the quality of the goals to which they are dedicated, that structurally influence whether or not microcomputers will be used to advantage. Especially important to understand are the demands of integrated teaching.

Microcomputers have to be seen as part of the complex pattern of classroom activity which will not yield quickly to innovative doctrines. The impact of those doctrines on school life and the function of teacher routines must be seen as a means to consider the potential of microcomputers.

(2) Research questions

The aim of this research and development project is to answer the following questions:

1. How can a computer simulation fit into classroom routines associated with integrated SES work?

2. What adjustments to their routines and to their curriculum do teachers have to make to use the available computer facilities in an integrated fashion?

3. What beliefs do students have about the computer as a source of information?

4. What do students focus on in considering their experience of the unit overall, and what role does the computer play in their assessment?

5. How do students think about the SES units, and what ro do their science experiences (including computer experiences) play as compared to the other elements of the integrated unit in influencing their thinking about the topic?

(3) Research activities

Our intention was to work collaboratively with the teachers. We were interested in the process of adaptation; therefore, the teachers' responses and ideas at every phase of the project were noted and incorporated into the study. Through participant observation and action research we explored the mutual adaptation of new information technology and existing classroom routines. The adaptation unfolded within the context of a "real-life" classroom where practical difficulties, such as access to the computer centre and scheduling constraints, had an effect upon the study.

The researchers and teachers collectively produced an integrated study unit on the theme of fire which included a computer simulation of a hands-on science experiment. We used the unit with two classes: Grade 4/5 and Grade 5/6. The unit comprised four elements: science studies of combustion; social studies focusing on historical, cultural, and technological aspects of fire; language arts activities involving reading myths

and making up myths about fire; and mathematics activities involving producing and interpreting line graphs based on the experiment and on a simulation of the experiment on the computer.

In order to explore students' beliefs about the computer, we videotaped them during the unit and interviewed 12 students after their work on the unit. We recorded their ideas about the computer as a source of information and their assessment of the role played by the computer in the context of the total unit.

METHODOLOGY

The study took place in three phases: planning, designing, and teaching the unit. The data, collected over a period of five months, October 1986 to February 1987, were recorded by the following means:

(a) taking notes at the planning and design meetings held with the staff. These notes, which were a record of decisions made collectively, then became agendas for further action; thus the process of data collection became part of the process of creating the unit.

(b) audiotaping, then transcribing, preliminary interviews with the teachers (see Appendix 2.A). These interviews provided data for profiles of the teachers, as well as addressing questions which were of interest to the larger research project. We audiotaped the sessions in which we planned the SES unit and then made transcriptions which became agendas for further action in a process similar to that described above. After the SES unit

had been taught, we audiotaped and then transcribed follow-up interviews with the two teachers (see Appendix 2.B) and 12 students (see Appendix 2.C).

(c) videotaping the unit in action. This involved videotaping the science experiment, the computer simulations, the graphing work, the students' responses to questions about the work they were doing while they were doing it, and the group presentations.

(d) collecting and analysing the students' work.

The data were collected using the techniques of participant observation, interviewing, direct observation, and document analysis. A description is given below:

(1) PARTICIPANT OBSERVATION

(1) Planning Phase

Through participant observation we worked with the teachers in planning the unit. Two planning meetings were held at the school during a 40-minute time slot, when half the students were in French class while the others were supervised by the computer consultant.

1. The first meeting was held on October 30, 1986. Notes were taken which were later transcribed and given to staff on November 5. These notes constituted an agenda for further action.

2. The second planning meeting took place on November 12, 1986. At this meeting we responded to teacher concerns about our data gathering by developing mutually agreeable procedures.

(2) Design Phase

During the design phase we continued to work collaboratively with the teachers in designing the unit. We took into account the constraints involved in limited access to the computer centre, and the existing schedule in the junior division which involved the withdrawal of students for subjects, such as music and French. Two half-day meetings were held at the Faculty of Education while supply teachers took over the regular classes.

1. The first design meeting took place on December 8, 1986, from 9:00 a.m. to 12:45 p.m. and included informal discussions during lunch. The formal part of the session was audiotaped. At this meeting, and in a follow-up letter, dated January 9, 1987, the staff members were asked to draw up a fairly firm teaching schedule of the unit to bring to the second design meeting. They were to include the date of the science experiment in the classroom and when the computer centre was booked for the simulation activities, so that the researchers could arrange to be present.

2. The second design meeting took place on January 16, 1987, between 1:30 and 3:30 p.m. The session was audiotaped. It was the final meeting before the start of the SES unit, and staff and researchers collectively worked out scheduling details. A timetable for both classes was designed at this meeting, and a

typed copy of the schedule was given to the teachers on January 20, 1987. The planned schedule differed slightly from what actually happened. See tables 1 and 2 for the chronology of activities involved in the Fire Unit (and see Appendix 1 for a detailed chronology of the unit design).

(3) Teaching Phase

The principal investigator acted as a participant observer on several occasions during the teaching phase:

1. He conducted the science experiment and the math follow-up for both classes. The teachers taught most of the activities of the unit and worked with groups during the experiment. These lessons were videotaped (see tables 1 and 2 for the chronology of the unit).

2. In collaboration with the teachers, he worked with both classes in the computer centre--observing, questioning, assisting--when students were doing the simulations. These activities were videotaped (see tables 1 and 2).

3. He led a class discussion in which the Grade 4s compared the live experiment with the computer simulation in terms of which results to believe and why: the students' recorded burn times from the live experiment, or the computer simulation. This discussion was videotaped.

Table 1 : Grade 4 Fire Unit Plan

Day	9:30-9:45	9:45-10:15	10:30-11:10	11:10-11:50
MONDAY Jan.19	L.A. # 1 .....) Spelling		SES # 1 Intro. to Fire theme Discussion of topics	
TUESDAY Jan.20		SCIENCE # 1 ^ Explore FLAME LIFE	MATH # 1 Discuss Charting Video on Graphing	L.A. # 2 Silent Reading Fire myth
WEDNESDAY Jan.21			SCIENCE # 2 ‡ Experiment	Math # 2 ‡ Averaging
THURSDAY Jan.22		L.A. # 3 Read aloud myth & answer questions	SES # 2 Choose project topics from book/idea display	
MONDAY Jan.26	L.A. # 4 Spelling	L.A. # 5 Read aloud fire story	MATH # 3 Graphing	SES # 3 Film on Forest Fire
TUESDAY Jan.27		SCIENCE # 3 ‡ ^ Simulation: changing beaker size	MATH # 4 ‡ Graphing/Predicting Discussion: Who is right?	SES # 4 Project activities
WEDNESDAY Jan.28	Compiling Booklets of written work		SES # 5 Project activities	
THURSDAY Jan.29		L.A. # 6 Comprehension exercises	SES # 6 Project activities	
FRIDAY Jan.30		SCIENCE # 4 ‡ ^ Simulation: changing # of candles	MATH # 5 Graphing: # candles	
MONDAY Feb.2		SES # 7 Project Presentations.....)		
TUESDAY Feb.3		SCIENCE # 5 ^ Sim'n: candle height		SCIENCE # 6 Film on Combustion
WEDNESDAY Feb.4	L.A. # 7 Reading activities		L.A. # 8 Writing fire myths	
THURSDAY Feb.5	L.A. # 9 Reading activities .....)		MATH # 6 Graphing: candle height	L.A. # 10 Spelling
FRIDAY Feb.6	Compiling booklets & finishing written work .....)			SES # 8 Video: Vesuvius
TUESDAY Feb.10			SES # 9 Project presentations ‡ .....)	

‡ Research team present to observe and videotape
^ In Computer Lab

L.A. Language Arts
S.E.S. Social and Environmental Studies

Table 2 : Grade 5/6 Fire Unit Plan

a.m.	9:00-9:45	9:45-10:15	10:30-11:10	11:10-11:50
p.m.	1:00-1:35	1:35-2:15	2:30-3:00	3:00-3:30
a.m. MONDAY Jan.19			Grade 6 MATH # 1: Graphing	Grade 5 MATH # 1: Graphing
p.m. MONDAY Jan.19	Grade 5/6 SES # 1: Intro.to Fire			
p.m. TUESDAY Jan.20		Grade 5 & 6 SCIENCE # 1 ‡ Experiment	Grade 5 & 6 MATH # 2 ‡ Averaging	
p.m. WEDNESDAY Jan.21	Grade 5 & 6 SES # 2 Project activities	Grade 5 & 6 SCIENCE # 2 ‡ ^ Explore FLAME LIFE	Grade 5 & 6 MATH # 3 ‡ Charts/Graphs	
a.m. THURSDAY Jan.22	Grade 5 & 6 SCIENCE # 3 ^ Size of beakers		Grade 6 MATH # 4 Graphing	Grade 5 MATH # 4 Graphing
a.m. MONDAY Jan.26	Grade 5 & 6 L.A. # 1: Spelling			
p.m. MONDAY Jan.26	Grade 5 & 6 L.A. # 2: Composition			
a.m. TUESDAY Jan.27	Grade 5 & 6 SCIENCE # 4 ‡ ^ # of candles		Grade 6 MATH # 5 Graphing	Grade 5 MATH # 5 Graphing
p.m. TUESDAY Jan.27		Grade 5 & 6 SES # 3: Project activities.....)		
p.m. WEDNESDAY Jan.28	Grade 5 & 6 SES # 4: Projects	Grade 5 & 6 SCIENCE #5:Candle height^	Grade 5 & 6 SES # 5: Projects	
a.m. THURSDAY Jan.29	Grade 5 & 6 MATH # 6: Graphing			
p.m. THURSDAY Jan.29			Grade 5 & 6 SES # 6: Project activities.....)	
a.m. FRIDAY Jan.30	Grade 5 & 6 SES # 7: Projects		Grade 5 & 6 SES # 8: Project presentations ‡ .....)	
a.m. TUESDAY Feb.3	Grade 5 & 6 L.A. # 3: Composition ^			

‡ Research team present to observe and videotape
^ In Computer Lab

L.A. Language Arts
S.E.S. Social and Environmental Studies

[2] INTERVIEWING

(1) Planning Phase

The staff were interviewed in order to compile descriptive profiles and to gather data for the larger project (see Appendix 2.A).

1. The 40-minute interview with Mrs. Peters (pseudonym) took place during lunch on November 14, 1986, in the project office at Hampton School (pseudonym). The interview was audiotaped, and a summary was typed later.

2. The interview with Mr. Rawley (pseudonym) took place two weeks later on November 28, 1986. This interview was also held over lunch in the school project office. It was audiotaped, and a summary was typed later.

(2) Teaching Phase

Staff and students were interviewed separately about their experience of the integrated SES unit, the role of computers in the context of the unit, and students' understanding of the process of combustion (see Appendixes 2.B and 2.C).

1. On February 10, 1987, Mrs. Peters was interviewed in her classroom during a spare period (see Appendix 2.B). This 30-minute session was audiotaped and later transcribed.

2. On February 13, 1987, Mr. Rawley was interviewed in his classroom while his students were in music class. The same

questions were asked (see Appendix 2.B). This 40-minute interview was audiotaped and later transcribed.

3. Over the course of two days, February 17 and 18, 12 students were interviewed: four Grade 4s, three Grade 5s, and five Grade 6s. Students were taken out of regular classes, one at a time, to be interviewed in the project office at the school (see Appendix 2.C). These interviews were audiotaped, and a verbatim transcription was made where appropriate.

[3] DIRECT OBSERVATION

(1) Teaching Phase

The research team observed both classes while the unit was in progress (see tables 1 and 2 for the Fire Unit plan). The team was not present for the entire unit, but observed and videotaped the following segments:

1. the science experiment in the classroom and the math follow-up
2. the computer simulations in the computer centre
3. a Grade 4 discussion comparing the simulation with the live experiment
4. the group presentations

An edited half-hour videotape was later produced; it contained key scenes from each element of the unit.

[4] DOCUMENT ANALYSIS

All the student worksheets relating to the science experiment and computer simulations were collected and itemized (see Appendix 2.D), and the graphs were examined. We collected the posters which Grade 5/6 students had made to illustrate their presentations (see Appendix 2.E for a list of presentation topics). The Grade 4 folders were studied and the work was enumerated (see Appendix 2.F). We read the myths created by Grade 4 students about how fire came to earth, and we read the accounts of learning about fire that were written by Grade 5/6 students.

THE SCHOOL

Hampton School is located in the centre of a quiet residential area where the homes, as well as the school, are approximately 30 years old. Recently, the number of students has dramatically increased. This reflects two new housing developments which are adjacent to the original neighbourhood, but situated within the school area boundaries.

THE TEACHERS

Mrs. Peters (Grade 4/5)

Mrs. Peters has been teaching for 16 years. She sees her role as an organizer: "I like to know what's happening before it happens"; "I expect the kids to be as organized as I am--or

almost"; and "I like to know where children are, that is, what page they are on, where they are in the notebooks."

She emphasizes the importance of beginning where the students are. Her first goal is to assess the children and discover their needs, which she does mainly through informal methods. She says that children learn by example, through observing: "At this age kids mimic what they have seen." Consequently, she tries to be a good model. She sees the need for structure and consistency, noting how children like routine. She adds, "If they are happy, I'm happy."

She tries to guide her students to discover for themselves how to do assignments and become independent.

Although she constantly changes the physical set-up of her room, she comments that, " The learning environment is very standardized.... I don't change a lot in terms of what I do with the kids."

Most of the work she does is text-based. She uses texts and some drills in mathematics. In language arts, her main resources are readers and labs. Because students need to master the skills of reading, she uses labs which focus on skills, are sequenced, and provide record-keeping provisions.

Mrs. Peters carries out a daily uninterrupted silent reading program (SQUIRT) and uses the new County writing folders with her class: "We try not to direct kids what to write, but it's hard not to."

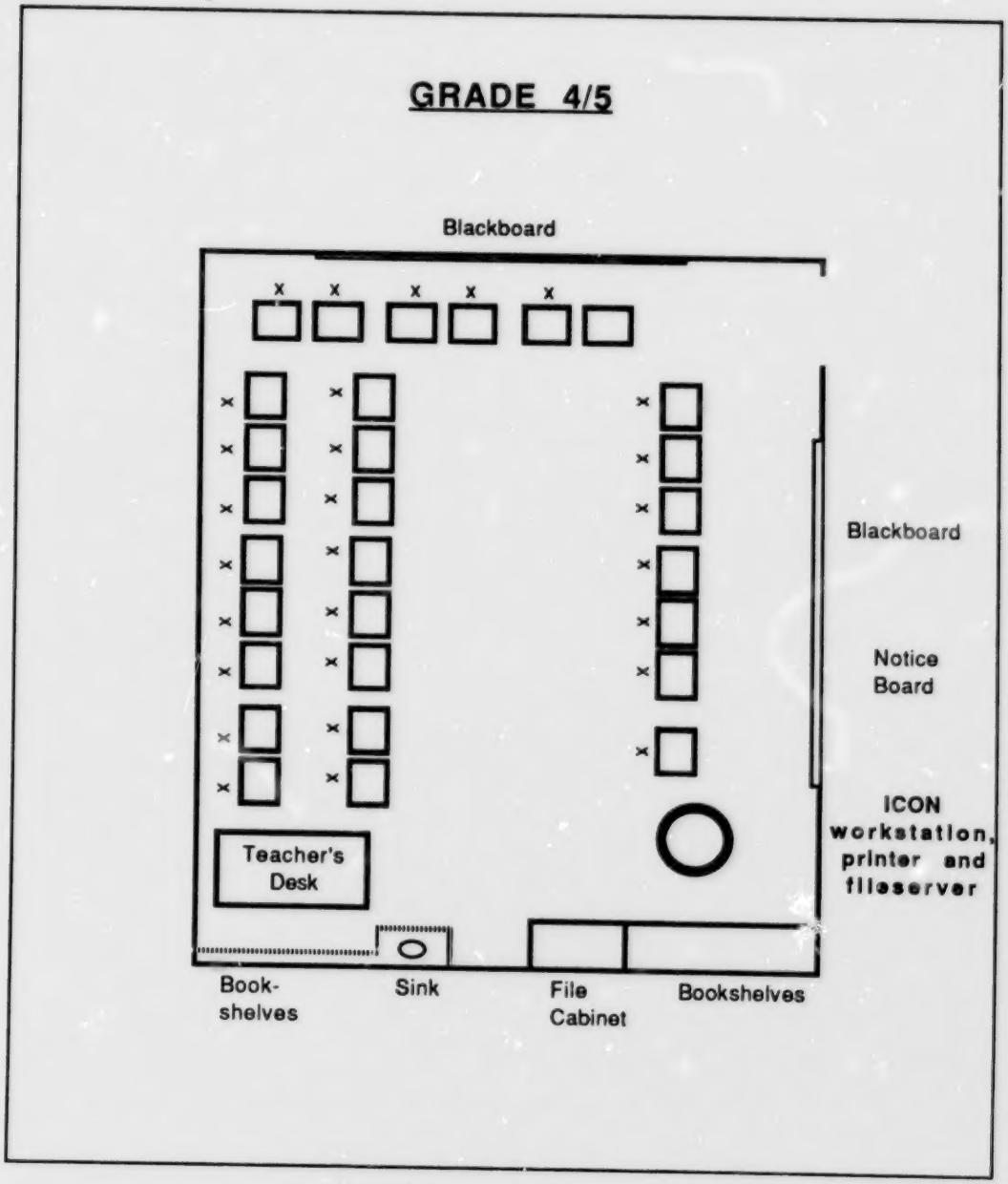
Mrs. Peters has had experience with LOGO, but much of the computer-based learning is new to her. She is eager to learn it herself, then introduce it to her class. LOGO, for example, will tie in nicely with her current geometry unit, and she feels the children will learn more about angles and lines from LOGO than from a text.

Soon after Mrs. Peters received the computer in her classroom, she organized a rotating schedule which allows the children to have 10 minutes of free time on the computer. She was studying "Computers in the Classroom, Part I" with the Board computer consultant while this study was in progress and, when we first came to the school, she was heavily involved in organizing various class activities in preparation for Remembrance Day.

Mrs. Peters' Classroom

The physical layout of the classroom is diagrammed in figure 1. However, the room is often rearranged as required. The room is equipped with an ICON workstation, a printer, and a fileserver. The desks are usually lined up in rows. After some experimentation, Mrs. Peters has chosen a physical arrangement that prevents the class from being distracted when one or two students are working on the computer.

Figure 1. Classroom Layout - Grade 4/5



Mr. Rawley (Grade 5/6)

Mr. Rawley, whose interests include music, swimming, fishing, and camping, is an experienced teacher who has taught in many Ontario schools as well as overseas. Although he has team-taught units with another teacher in the school, he favours an independent working style.

He likes to encourage and motivate students. "Everyone has something to contribute and should feel that they can." He wants to build student self-confidence, and feels the computer can make a large contribution here, as well as in motivating students. He wants to "provide an environment that's interesting and non-threatening." Freedom, he suggests, must be within a logically sequenced environment: "It's not license, but it's freedom."

In the past four years he has used the Socratic method, not using centres as much as he previously did. He varies his teaching style through the year, starting with fairly structured teacher-centred learning situations. These involve a great deal of review of basic skills, such as spelling, punctuation, and arithemetic facts. He then progresses to using study groups and centre activity with a greater degree of student interaction.

With the changes in teaching style have come changes in the learning process. He starts by transferring knowledge from teacher to students; later on learning takes place more through social interaction. He is confident that when the students move through learning centres they will not have problems with

spelling, grammar, or tables, because he knows that they have covered it through the lessons he teaches in the first half of the year. At the beginning of the year the room is arranged in rows, and in the second half of the year it is arranged in groups.

Mr. Rawley uses mathematics textbooks in Grades 5 and 6. Children work independently with their books and he works with individuals who are having trouble. He also uses commercially available workbooks and worksheets a great deal in all areas. He enjoys teaching reading and comprehension, discussing in small groups what they have been reading. In this way he sees how they have been gaining insights. He reads daily to the class--just for the pleasure. He finds that the students enjoy his dramatic reading.

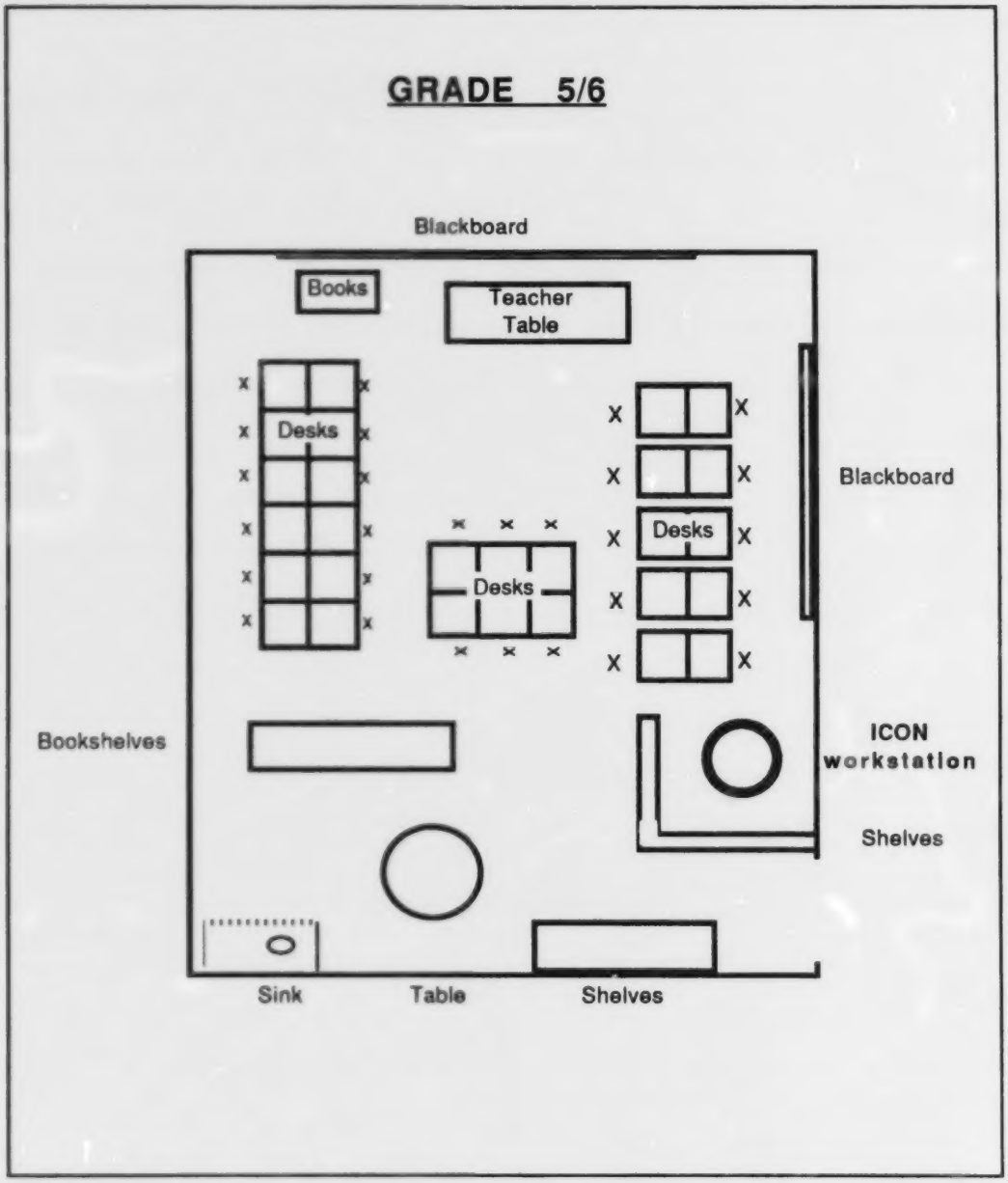
At first he was not enthusiastic about computers when there was only one in the school. "It's different now I have one in my classroom. ... I think the computer is an exciting thing, the way it is in this school--there are enough of them to go around." He is particularly keen on having a bank of computers in the computer room: "It is beautiful... 15 computers with 30 kids, 2 at a computer. They will get a chance to talk to their partners."

In addition to regular school activities and participation in this project, Mr. Rawley spent much of December in helping to produce the school's Christmas play.

Mr. Rawley's Classroom

The room is equipped with one ICON workstation, which is enclosed on three sides by a wall and two bookshelves. Mr. Rawley's students use the computer in this room less frequently than the bank of computers in the computer centre. The desks in the Grade 5/6 classroom are arranged in clusters (see figure 2 for the physical layout of the room). This cluster arrangement marks the second half of the year when Mr. Rawley moves from a more structured approach (desks in rows) to a situation where he encourages learning through social interaction and rotation of students through learning centres.

Figure 2. Classroom Layout - Grade 5/6



CHAPTER 2: THE COMPUTER AS A RESOURCE FOR LEARNING

INTRODUCTION

The computer provides a resource through which the curriculum can be taught; it enables the teacher to carry out more effectively what he or she has planned. At the same time, innovative software can suggest new ways of teaching the curriculum and running the classroom. The relationship among the promise of the computer, the curriculum, and the classroom is complex. Often, software only slowly finds a place in what is usually done in the classroom; yet through it new ways of doing things can be suggested. It is that interaction that is the focus of this chapter and the next. On the one hand we are interested in what the computer can offer to the teaching of social and environmental studies, and on the other how computer-based activities can be adapted to everyday classroom life. In this chapter we consider how the software contributed to student learning: the computer as resource. In the next chapter we consider how the computer fitted into everyday life in the classroom.

THE COMPUTER AS RESOURCE

In order to learn more about the contribution of the computer simulation to learning, we analysed two sets of related data from the student responses to the worksheets they were given. The first set of data showed what they thought about the process of burning itself and about how they would investigate such a

process. The second set of data showed what they thought about the role that simulation plays in investigation (see Appendix 2.D for worksheets).

Five activities comprised the computer-based learning. They were: graphing; prediction; controlled experimentation; understanding combustion; and knowing how we know. We turn now to a description of each of these activities, before considering how this computer-based learning can contribute to conceptual change.

COMPUTER-BASED LEARNING ACTIVITIES

(1) Graphing Skills

Using a worksheet designed by the team, students were asked to graph the results of their classroom experiments having averaged the results of their three trials. The concept of an average posed few problems for the Grade 5/6 students, but Grade 4 students had to be taught the basic idea. As part of the scientific-process objectives, students were asked orally why different trials gave different results and how taking an average helped us deal with those results. The students prepared a line graph to show the relationship between container size and how long the candle burned. The students were then asked to determine how long a candle would burn if three other different-sized containers were used. In order to determine the value, they had to determine these numbers from the graph itself. They noted these values on their worksheet in preparation for doing the experiments on the computer, using the container sizes they

had chosen. In this way they were able to compare the values taken from the graph with those generated by the computer. The students were asked to assess the correspondence between their values and those of the computer.

(2) Prediction

In their computer-based experimentation, students were asked to predict the flame life for each trial they ran. The computer kept a record of their predicted and actual burn times. Thus, the students could monitor their progress and use the accumulating data as a basis for further prediction.

(3) Controlled Experimentation

While students had investigated the relationship between container size and flame life in the classroom, they used the computer simulation to explore the relationship between numbers of candles and flame life. Given the management and safety problems at this level, the computer simulation affords a safe way of extending the investigation. Students were asked to collect data and interpret the graph of that data as represented to them by the computer. In this case, the pattern of the graph was different: inverse rather than direct relationship, and curvilinear rather than linear.

(4) Understanding Combustion

The worksheets also provided space for students to express the relationships between container size and flame life. They had

graphed this relationship for three container sizes themselves, and they had seen a computer-generated graph based on three other container sizes. They had an opportunity to see similar graph shapes in both cases as a basis for inferring a pattern of relationship between variables.

The students were asked to give causal explanations for the relationships among container size and numbers of candles and flame life.

(5) Knowing How We Know

Students were asked to decide which results they would believe if the results taken from the graph and those of the computer differed. They answered this question on the worksheet. A follow-up discussion back in the classroom considered the question: "What does the computer 'know'?" The question formed part of the larger question: "How do we know things in science?" This question had already been addressed when the class considered the variability of results when they carried out repeated trials.

These are the computer-based activities which formed part of the unit on fire which we planned in collaboration with the teachers. The computer-based work did not take place in isolation from other activities; indeed, the point of these particular activities can be found in the overall plan for the unit, which involved diverse approaches to the theme.

LEARNING OUTCOMES

What did the students learn? In order to answer this question, we analysed the worksheets of the students and followed up this analysis by interviewing some of them. The worksheets provided us with an overview of the performance of the students, while the interviews allowed us to probe the understanding of the students. We begin with the worksheets.

Worksheets

Virtually all of the students inferred the direct linear relationship between container size and flame life and the candle going out because air or oxygen is used up. The students mentioned oxygen more often than air. Two students in Grade 5 thought that a wet wick might have caused the candle to go out. The Grade 6s had the most diverse list of possibilities, including smothering by smoke, wet wick, and vibration of the table.

Similarly, the students inferred an inverse relationship between number of candles and burn time. On the whole they thought that more candles would use up oxygen more quickly and thus go out sooner. However, there was a greater diversity of hypotheses suggested to explain the results of this experiment. Some students thought that the greater number of candles would occupy more space, thus decreasing the oxygen available.

On the whole, students found that the burn times read off the graph were similar to values generated by the computer. Nearly all children were able to successfully interpret their

graphs. The computer allowed them to check their ability to use graphs in this way.

Students were asked to consider which results they would consider correct: values from the graph or those from the computer. The Grade 4s thought the computer was right, while the Grade 6s thought that the actual experimental values were probably right.

Student Interviews

In order to explore student learning in greater depth, 12 students were interviewed (four in Grade 4, three in Grade 5, and five in Grade 6). These students were selected by their teacher as ones who would not find the interview intimidating, and who would likely be forthcoming about their experiences. They are among the more able students in each class.

The students were asked to talk about what they learned and the role the computer played in that learning. Two main topics associated with learning were covered in the interview: the factors affecting flame life and the nature of combustion, and the role of the computer simulation in learning (see Appendix 2.C).

Grade 4

(1) Factors Affecting Flame Life

Students said that making beakers smaller and increasing the number of candles decreased flame life. Smaller beakers contain less oxygen, the students said, so the candle goes out more quickly, and more candles used more oxygen so they used it up more quickly. Students were able to apply their knowledge to solve a word problem about candles that burned for different lengths of time. Students thought that the size of the candle mattered, because bigger candles occupied more space and would thus diminish the oxygen supply.

(2) The Process of Combustion

Students said that flame, smell, smoke, heat, colours, and light were products of combustion. They focused on the observable phenomena of the process. These are the things the computer was not able to simulate, but are what students noticed about the process. Students were asked to say what they thought smoke was: smoke was dust, ash, something that uses up oxygen, the stuff that "comes off" from burning; smoke was a rather solid thing, rather than being a gas. Students said that the candle itself melts in the burning process. "If the melted wax that is produced is collected, could the candle be restored if a wick was added?", we asked. One thought yes, one thought no, but none were quite sure why. One thought that, as well as melting, the candle had been burned but that had not necessarily resulted in any loss of

candle matter because it was the wick that had burned, not the wax. Jonathon said: "There's nothing gone. All that's lost is the wick. The wick was burnt."

(3) The Simulation

Students were asked to compare actual and simulated experimentation. How did they differ? Students commented on the range of choice of containers and candle sizes available in the simulation. The built-in timing, the graph, the safety, and the prediction provided by the computer were noticed. However, the computer did not have the real colours, the smoke, the flame going out, the smell, and the melting wax of the real experiment; and the computer restricted the sizes of the container. As Carolyn said: "When the candle goes out, you can't see the smoke and [it's] not the same colour. When the candle's finished burning, the flame goes out. On the computer it just turns white."

(4) The Process of Experimentation

The students were asked again to compare computer results with their own results from the actual experiment. If there were differences, which would they trust?

One thought the actual experiment should be trusted; two thought the computer; and one thought both. Here is what they said:

> "I'd believe the one that we did. We did the actual thing."

"The computer, I think; because the computer has very precise timing. If you were not watching your watch...."

"Probably the one on the computer. The person that was making the programs checks it over a few times. I might not have timed it properly."

"Somebody could have not put the program in right. I might not have looked at my graph right."

Discussion

Students are impressed by the precision of the computer and aware of errors they might make. Yet the computer could make a mistake as well if it was not programmed properly. On balance, the computer is to be trusted. Although the computer is precise, it does not provide the sensations that students notice in trying to make sense of what they observe. They attend to the obvious features of the process: smoke, a rather solid substance, is given off and the candle melts. The underlying processes are not apparent. They have the idea of oxygen being used up, which they all affirm, but they are not clear how oxygen is involved. They believe that smoke is a solid and that the candle melts. Although students believe that oxygen is needed to support combustion, they apparently have no idea how candles use oxygen. One student thought that the wick is burned. Students focus on the obvious aspects of the process. They are not able, however, to use the idea that oxygen is needed for combustion in order to understand the factors that affect combustion. They are surprised that taller candles do not affect the flame life.

Grade 5

(1) Factors Affecting Flame Life

Like Grade 4s, the Grade 5 students understood that varying the number of candles and the size of the container could alter the flame life. They gave rather more elaborate reasons why these variations made a difference. For example, in thinking about why five candles went out more quickly than one candle, Jeremy said:

> "It would burn for a lesser time because they're taking up more of the oxygen space (and also) it takes a certain amount of oxygen for one candle to burn and you double that for each candle (added). (There is) the same amount of oxygen in the container to start with, but these five use it up faster."

Colin also thought that loss of oxygen accounted for the shorter burn time.

All the students thought that changing the size of the candle should make a difference to the burn time. They were puzzled that such a difference did not occur when they studied this variable when using the computer.

Candle size would make a difference, they said, because smaller candles would have smaller flames and less wax and would consume less oxygen. They believed that taller candles would have access to less oxygen than shorter candles either by taking up more space, or by being high up in the container.

(2) The Process of Combustion

Kate said that when a candle burns it gets smaller and smoke which is given off comes from the wax. Jeremy thought that carbon dioxide was given off. He said that the smoke comes from the "burned up" oxygen, and also the wick, and that the wax turns to liquid. He believed that some of the wax is still there but a "missing bit would have gone up in the air." Colin said the flame gave off light, heat, smoke, and odour. "Smoke is burnt oxygen," he said. Most thought that the wax melts but is not burned, and the candle could be made again out of the melted wax.

(3) The Simulation

The students noticed that the computer did not show the candles floating in a tray, or smoke, or melting wax. "The container was only a sketch," they said. They noticed that the trial times varied in the real experiment, but not on the computer.

However, the computer does the experiment at the push of a button and you can predict, pick many beaker sizes, and get a graph if you want.

(4) The Process of Experimentation

Kate thought the real experiment should be trusted, even though you could make a mistake in timing the candle. "In the class most people got the same answer most of the time, so you felt you were right," she said. Jeremy thought the actual experiment should be trusted because "you've done it and you can tell what it's going

to be ... because you've got control." Colin said he would believe the actual experiment because:

> "Computers are sometimes wrong; if you do it in real life it would be realistic and you could believe it easier.... If the computer is programmed wrong, it could be wrong every time. (Humans) don't make the same mistake again; they learn, but the computer doesn't."

Discussion

These students were impressed by the push-button ease of the computer and its range of choice and graphical display, but noticed that elements of the actual experimental design were missing, as well as the smoke and smell. They appeared to have quite clear expectations about how the system should behave. Therefore, they were puzzled by the failure of the computer to confirm their expectations about the effect of candle size on burn time. Perhaps the design of the simulation influenced their views about what system to trust: real or simulated. Their understanding of the process of combustion depended less on obvious features; they included non-visible phenomena and processes in their accounts, but were not clear just how the pieces fitted together.

Grade 6

(1) Factors Affecting Flame Life

The Grade 6s were able to describe the relationship between variables quite precisely and to correlate them well. Colin J.'s

response is typical:

> "The candles always need oxygen to burn and a jar only holds a minimum amount. As we increased the size of the beaker, the candle burned longer because [of] the bigger space to hold the oxygen."

Similarly, the effect of the increased number of candles was clearly understood. Laurene said:

> "Five candles would burn for less time because there was the same amount of oxygen but more candles to burn it up."

The students expected candle size to make a difference because the bigger candles would occupy more space. A larger candle would also have a larger flame and so need more oxygen. Colin suggested that measuring burn time in tenths of seconds would reveal differences because of candle height. Laurene made the same suggestions.

(2) The Process of Combustion

The students said that the products of combustion are carbon dioxide, heat, light, and smoke. Some said that smoke is ash from the wick; burnt wax; or burnt oxygen. They did not believe that the candle could be reconstituted from the melted wax because some of the wax is consumed in the burning process. As Laurene said:

> "You would not get as much; half would be missing. It has turned into smoke; maybe into carbon dioxide. It has gone from solid to liquid to gas."

The students are agreed that the wax has been burned and has

undergone a change of state into smoke or carbon dioxide. The students have a clearer idea about the invisible processes that account for the things they can see. The rudiments of a chemical theory of combustion are at work in their explanation, but none appeared to have clearly in mind that the stuff of wax combined with the oxygen to form carbon dioxide. Their descriptions of the process are still tied to everyday language and to surface phenomena. Nonetheless, the basic idea of combustion is immanent in what they say.

(3) The Simulation

Colin J. thought the timing of the computer was less accurate than the real experiment (since he had used a stop watch with 1/10-second timing). He thought the computer could make mistakes by being mis-programmed. On the computer the candle did not "fizzle". Laurene found just pressing the button to be "fake". Katherine said "real candles and real jars were missing and you could watch it [actually] happening." Paul also missed the "action", found not having to set up the experiment unreal, and was not sure about the computer results. Michelle missed the three-dimensional character of the actual experiment.

On the other hand, Colin J. liked the idea that the computer could graph the results, that it gave a choice of containers and numbers of candles, and that it was safer. Laurene also liked the choice, the graph, the built-in timing, and not having to set up the experiment. Katherine agreed that the experiments were easier to do on the computer. She liked the graphs as well.

Paul also thought that the experiment was quicker to do on the computer and he liked the graph. Michelle thought the built-in timing useful, being able to make predictions was a good experience, and she too liked the graph, but wished that the computer could print it for her.

These students appreciate that the very virtues of the simulation are the same as its defects. It is quicker to do things using the simulation, but unreal because you only have to push a button. All said they liked to see a graph of their results.

(4) The Process of Experimentation

Colin J. trusted what he called "real numbers":

> "I'd go with the real numbers because the computer can make a mistake .... In the computer, if it makes a mistake once it usually will make it again, but if you make a mistake you can correct yourself."

Colin thought the real thing more exciting:

> "On the computer you don't have the feeling of actually being able to do it yourself. [In the real thing] you actually have a feeling of saying I feel great; I got this right. The computer didn't do it; I did all the work!"

Laurene also trusted the real experiment, because even though she could make a mistake, so could the person programming the computer: "The computer could keep on making the same mistake." Katherine also thought the computer could be wrong. Paul said that he would trust the real thing: "If you are good, you could be sure you did it right." Michelle agreed with the rest; the real experiment is to be trusted, because it is real.

Discussion

These students think that if a computer is mis-programmed it will not learn from mistakes as humans can. So the computer would go on and on repeating the original mistake, while they, the humans, are able to detect their mistake. The Grade 4s thought on the whole that the computer results were the ones to trust; the Grade 6s think that humans are to be trusted. They appear to have a better idea about the limitations of machine "intelligence".

While student conceptions of natural phenomena and computer-based learning will be discussed in greater detail in the last chapter, we can observe a number of trends here. We have seen the shift in perceptions of trust from computer simulation to human-controlled experimentation. There has also been a shift from a perceptual to a conceptual understanding of combustion. The Grade 4s explain the process in terms of readily visible phenomena; the Grade 5s, and more so the Grade 6s, use non-visible phenomena in explanation, and link observable phenomena together in logical strings. Thus, bigger containers mean more oxygen, and more candles mean less oxygen for each if given no increase in air supply. Carbon dioxide is mentioned first as a product of combustion rather than smoke. Although the candle physically melts, it is also chemically consumed.

This having been said, none of the students we talked to appear to possess a well-developed idea about the chemical processes involved in combustion, as we would not expect them to, given the overall goals of this unit. However, there is reason to

think that students could profit from exploring the differences between their models of burning and those of science. Most students were able to manipulate the data effectively through averaging, interpreting, predicting, and generalizing from graphs. Students appeared to be successful in using data tables to predict and graphs to determine burn times for different sizes of containers, and they appreciated the prediction and graphing features of the computer. Such processes seem open to systematic development in junior classes. The student worksheets and interview data suggest that the Grade 6s could profit from systematic instruction on this topic, a fundamental part of the larger topic of the particulate nature of matter.

Our videotapes indicated that students were also aware of the role that repeated trials play in establishing patterns in nature, of the importance of accuracy in measurement, and of the role mathematical procedures can play in helping to classify and represent those patterns. These students responded in a lively and engaged way when they were asked questions about these matters in class, either by their teachers or the investigator. These whole-class responses, which we videotaped, tend to support the conclusion that the responses of the individuals interviewed were not atypical.

Studying Patterning

Students can profit from considering their computer experiences in a reflective way. The computer has the capacity to simulate situations in which students can explore their own pre-conceptions about what is going on in the world. Students can use the computer as an instrument which reflects back to them the consequences of their way of approaching problems. It is in the sense of "back-talk" that we want to develop ideas about how computers can contribute to conceptual change.

Students do not approach school tasks empty-headed. They have ideas about how to probe phenomena which they encounter, in order to see if they are patterned (Driver 1986). They have ideas about how to explain the patterns they discover. Students seek out patterns in their experience. We can see this in how students use the computer. We found that students enter values in order to determine if there is a connection <u>at all</u> between container size and flame life; not just to find out <u>what</u> the connection is, which was the task set for them. They imposed their own agenda: "Find out if the system has a pattern at all." Thus patterning itself becomes the task.

The computer simulation makes it relatively easy to pursue the study of patterning, because students can gather data quickly without having to re-set the experiment, and without encountering the errors that could creep into actual experiments because of faulty experimental procedure. While the actual experiment

provides a very satisfactory basis for gathering data about the nature of the connection between size and flame life, the computer provides a better basis for exploring patterning, but only if the program can simulate the variability of results that accompanies actual experimentation. Mathematically generated patterns, with no variance, simply do not reflect the reality of experimentation. Patterns can be discerned, not because of some mathematical exactitude in the data, but because of an emerging apprehension of pattern based on perceptions of tendency, which students eventually express as inferences about the data.

There is thus another qualifier to be introduced. Students should be prompted to make explicit their emerging ideas about patterning. To do this, they can be asked to predict the next result, as they did in the FLAME LIFE program.

We asked some of the students how they predicted the next value. Their answers are interesting:

> "[I] had to guess. Maybe I remembered what my time was for the last time [I did the trial]." (4)
>
> "It goes in a pattern." (4)
>
> "[Prediction came] from your mind. I just guessed them." (4)
>
> "By looking at what your last time was, or looking at your graph." (5)
>
> "By knowing what was going on. If you had 5 candles, and the time was 11, you'd know it would be lower if you had 4 candles because it would take up more oxygen." (5)
>
> "If the size of beaker and the candles are the same, but there are two candles I'd cut it in half. [When I did it] it was pretty close." (6)

"I did it by how big the jar was, or just estimating. I knew how long one candle would burn .... It was surprising when you added a second candle, how quickly it [went out]." (6)

"You could usually tell if it was the size of the beaker. After a while we figured out how to get it exactly." (6)

"The smaller it gets [container], so is the number [flame life]." (6)

As we have seen, the older children begin to infer a patterned relationship that gives them a clue to prediction. The relationship is based on a theory about what is happening which suggests, at least, a direction for the relationship, if not an accurate picture of it.

Student Conceptions

If there is little or no variation in results, students do not receive apparently disconfirming, or at least anomalous results, which might upset their idea about what is going on. Yet, without such variation, they receive a false impression about doing experiments and discerning patterns. It is only in the mind's eye that a pattern actually exists, because such a pattern has to be imposed on variable data. It is important that the simulation of phenomena exhibit realistic variation, and that the teacher, or the program, help students to cope with apparent anomalies. The power of preconception is likely to be sufficient to overcome small slips in the way data are patterned, as long as the general tendency of the data conforms to expectations. When students do not encounter expected patterning, they impose it anyway. There is evidence for this tendency in our studies of flame life.

The back and forth gathering of data, and the repeated trials using the same values for container size, can now be thought of as ways for students to check whether or not their preconceptions can be confirmed. Students confronting a task in school likely expect to find patterning, but have to confirm this and, if necessary, re-confirm it. We can see this in the way students gather data in the cases we have considered.

On the whole, the students quickly align prediction with actual values for flame life which occur by changing container size. Notice, however, the surprise expressed by one student about the rapid reduction in flame life when two candles were used instead of one. That graph not only portrays an inverse relationship, but an exponential one as well. Two candles go out more quickly than you would expect if you had a linear model in mind.

It is the lack of effect of the height of the candle on flame life that most surprises students. The oxygen/air supply model they envision leads them to think that the increased bulk of candles will make a difference to the bulk of oxygen supply available and hence to flame life. They are right on the first count, but not right on the second. Although the effect is there in theory, in practice it is smaller than can be detected using the simulated and actual experimental set up. Even determining when one candle is out is difficult and introduces considerable variation into the results. Students expect the smaller candles to go out sooner, but in the simulation they do not. Some think the effect of height is indeed small and wonder why the program

does not measure flame life in tenths of seconds. This is especially true if they have used that unit earlier to measure flame life in the classroom, using their own digital watches. Another student simply said that he found that the height had made a difference in the simulation even though it had not. He had imposed this pattern on the data.

Students expect to see a difference because, in their mind's eye, the reduced bulk of oxygen should give rise to reduced flame life. Indeed, one of the teachers was critical of the simulation because there was no variation in results in the trials with height of candle, and there seemed little point in persisting with the trials. Very soon, it seemed, the question of candle height, for the students, was a settled issue: no effect.

These comments suggest that students still believed that the bulk of the candle affects flame life, and many expressed surprise when the simulation did not confirm their preconception. Earlier experiments with container size and number of candles had come out as expected, but not the effect of height. Height created conceptual conflict.

Learning from Simulation

Students and teachers, at this juncture, could go on to talk about why the simulation did not conform to their expectations and what that signified. Together, they could reflect on the factors that might be involved in causing the candle to go out. They could be challenged to defend the adequacy of the supply-of-oxygen model they so firmly believed. They could also consider

matters other than their theoretical expectations, which have to do with how we measure flame life and how actual measurements compare to the simulation. Indeed, these matters were discussed as students completed their worksheets, talked to their partners at the computer in the lab, and in discussion back in class.

The simulation itself was analysed. How realistic was the simulation? Students asked these questions of each other during their work at the computer. These questions spring naturally from their experience, and the students require a classroom in which questions like these can be asked; a classroom in which it is important to get to the bottom of things. Doing this kind of work is a way in which the teacher can express the importance of getting to the bottom of things; of the value of persistence, risk taking, and speculative thought. That is the way simulations like FLAME LIFE can contribute to conceptual change.

Critically looking at the simulation can become an occasion for getting to the bottom of things. This means seeing the adequacy of existing conceptions of scientific theory and method. Beyond that, it is an occasion for showing each other how much we care about getting to the bottom of things; how willing we are to learn from our experience more about the world and more about ourselves. This is the promise of computer simulation. This is the promise that the teachers discerned in the experience of their students.

The experience of the students with the height of the candle raises important questions about the role computers can play in helping students test the adequacy of their preconceptions. How can the promise be fulfilled?

The answer is the same here as it was for the question of how computers can play a role in changing teaching practice for the better. A critical process of reflection has to accompany the experience of using computers. The promise of computers is that they can provide experiences which, if reflected upon, yield new and more productive conceptions of practice in teaching, and of patterns in the phenomenal world. Teachers and students can learn more about themselves and each other through reflective practice.

Reflection on practice can yield powerful perspectives on that practice when teachers consider their use of computers in relation to their educational values. How can students in a similar way confront their own thinking about the reality of the world? Let us pursue the example of the height of the candle to show how this might happen.

Students bring preconceptions to thinking about phenomena, although they may not be aware of the nature and function of these preconceptions (Driver 1986). They do not come empty-headed to experience, even though they may think they do. On the contrary, they bring to any new experience, preconceptions based on their own need to make sense of the world.

One way children make sense of the world is to see patterns in everyday experiences. School encourages this. Weather records are kept, for example, and recurring festivals are celebrated. The cycle of seasons is observed and they too are celebrated.

These preconceptions might better be called organizing conceptions: they are the ideas out of which experience is constructed. These conceptions make possible safe and satisfying passage in the world. The imposition of pattern on experience is fundamental. Making sense of that pattern in terms of some other conception comes later.

Unless students understand their own conceptions, they have no way of assessing the usefulness of alternative conceptions. While the computer can provide appropriate challenges, the teacher has to help students make sense of what those experiences signify. How this can be done cannot be anticipated in advance, because what the teacher says to the student depends on what conceptions each student brings to his or her experience. Thus, the computer itself cannot be relied upon to help students make sense of this experience, because it cannot be programmed in advance to anticipate how different students will make sense of their experience. The role of the teacher is crucial in exploring the significance of the student's experience with the computer. The computer is crucial in providing a medium through which students can test their conceptions against reality: a representation of reality that effective simulation can provide. Thus, the computer gives students access to a simulated reality

and can provide a record documenting their efforts to find patterns in phenomena. The discussion of patterning itself, how we search for patterns, and the role patterns play in how we understand the world, cannot be computerized. The teacher is central to the success of this process.

CHAPTER 3: INTEGRATING THE COMPUTER INTO THE CLASSROOM

In the preceding discussion we saw how computer-based activities can contribute to the process of inquiry and to how students can learn from their computer experiences. These aspects of learning easily find a place in the junior curriculum (Ontario 1975) and they form a natural part of the Fire Unit. How does the computer-based learning that we have just considered fit into the overall unit? In order to pursue this question we consulted our records of the way the unit was planned and taught, and we interviewed the teachers and students about their experience of the unit. It is to these analyses that we now turn, as we consider the integration of computer-based learning in the classroom.

Integration at the elementary level reflects a traditional and well-founded concern that school subjects not be studied in isolation from children's interests, and from what their development dictates. Usually the response to these concerns is to develop themes which can form the basis for an integrated approach to learning. In the unit under study here, the theme of Fire was chosen as likely to interest children as well as providing varied activities within the scope and resources of the school. These would be augmented where necessary using sources outside the school. The development of a thematic unit like Fire is not unusual; but the access to computer support for the unit is. Each teacher had access to 10 computers in the lab, as well as a computer in each room.

However, other resources were available. As well as the considerable experience of the teachers in planning units and choosing appropriate methods of instruction, Mr. Beckwith, the computer support person, provided in-service activities for teachers, and Mrs. Dudley provided technical support. The principal, Mr. Williams, is very interested in resource-based learning and supportive of the kind of thematic approach that the Fire Unit represents. Mrs. Monroe, the in-school resource teacher, is also strongly interested in integrated planning. Thus the development of the Fire Unit was undertaken in a supportive climate, with excellent human and technical resources.

Two important questions need to be asked about the role the computer can play in supporting thematic teaching. They are these: How does the computer foster curriculum integration? How can teachers adapt classroom routines to take advantage of the computer resources? We shall consider each of these questions in turn.

INTEGRATION WITH CURRICULUM

One of the most important aspects of planning an integrated unit is to find a suitable theme, and to develop activities in each of the subjects within the theme that support each other. This means, for example, that the science activities are supported by the mathematics ones, and that the science work has some bearing on the social studies project the students choose to do. Similarily, language arts activities and the other activities should collectively support the objectives of the thematic study.

Thus it is important, at the outset, to understand the objectives of the thematic study.

Fire is a topic which the team felt would interest students and which would allow important junior division objectives to be pursued. What were these objectives? Put generally, students were to gain an increased understanding of the processes involved in burning--the processes which are basic to the nature of matter itself. Fire is part of a fundamental technology almost as old as humankind itself. This technology manifests itself in many ways in modern society, but it is very old. Ancient efforts to make sense in the form of myths show how old is our interest in fire. These efforts also reflect proto-scientific views about the process, as well as poetic and religious expressions about the meaning of fire.

Students need certain mathematical skills in order to pursue a scientific study of fire, just as they need certain reading and research skills to explore other aspects of the topic. The unit should make provision for developing and reviewing those skills.

The overall design of the unit (see tables 1 and 2) reflects these concerns. An analysis of the work produced by students, given in detail in chapter 2, illustrates how subthemes of the unit were woven together. The student work, the classroom observations and participation, and the videotapes suggest interesting interactions within the subject matter of the unit. Study of early myths supports the students' own efforts to make sense of the burning process. They, like the ancients, are attempting to get beneath the observable aspects of the process by inventing

models to account for what they see.

This model-building process is reflected in the language arts work as well as the science. Similarly, in the science activities, students measure time accurately and compute averages, both of which are critical to the inquiry process. The science work provides a context for developing the mathematical operations; the former helps make sense of the latter. Our observations of the lessons (which we videotaped) suggest that the students quite clearly saw the need for accurate measurement and for an average and were keen to explore these problems. The videotape and student interview data suggest that these aspects of the unit worked well together.

Grades 5 and 6 presentations helped link the science activity to the themes of the unit (see Appendix 2.E for a list of presentations). The list of topics shows how fire, as an intellectual problem and a socially and technically relevant phenomenon, was treated in a unified way.

Students worked in pairs and in groups. There was a significant social dimension to the unit, and, as it turned out, quite strong feelings about doing experiments and working at the computer emerged. Mr. Rawley was aware of the affective dimension of the unit:

> "They had to share computers. They also learned that the computer wasn't a toy. [They found] that the experiments were taking them somewhere when they made a discovery. [The computer] demanded that they keep records; it disciplined their behaviour. They had to follow prescribed procedures; it wasn't just a game. The computer is motivitating; it does talk back to you. Students really become involved with it."

Mrs. Peters had similar views about student presentations:

> "They were interested in them. They had good resources; a box full of books. The interest was keen."

What contribution can the computer make to the integration of subjects? Answers to this question have come from a number of directions in this case.

Both teachers found that the different elements of the unit supported each other. Mrs. Peters said:

> "I think they were pleased to have one topic to study for two weeks. Just about everything they did was based on that. We haven't done theme work before. They enjoyed being active as well. The fire experiment made a big difference to them and knowing that they were going to the computer for a reason."

The computer contributed variety and accuracy. She said: "The variety of alternatives you have in setting up the experiment would require too much preparation. [The computer contributed] accuracy."

Mr. Rawley also found the elements of the unit mutually supporting:

> "They picked which topic they wanted to be part of [careers, disasters, history of fire]. They went to the library; they used the box of books. They decided to do anecdotal reports plus pictures. I was not involved unless they asked me; it was self-directed. It went smoothly because there was so much excitement carried over [from the other work]."

Mr. Rawley's comment about "going somewhere" with the computer program, taken with Mrs. Peters' observation about children enjoying the focus of the unit, suggests how integrated

units, with carefully considered subthemes, appeal to students. The theme gives a plot for the work: a story about something which goes somewhere.

The students enjoyed making presentations on the topic. It is interesting to see what aspects of fire they studied in their projects and what they thought they had learned from the experiments (see table 3).

Discussion

We have already considered the role the computer can play in supporting the subthemes of an integrated unit. An important theme of the unit was how to make sense of fire, both in terms of understanding fire from various points of view and also understanding different ways of knowing. Thus the mythic aspects of fire were considered as well as the scientific aspects. In this way, students could see that the way we study fire depends on our purposes.

By comparing simulations of the process with the real process, students have to ask how they know what they know. The capacity of the computer to do the calculations quickly and represent the process and the data graphically, provides an accessible tool for asking questions about how we represent things to ourselves. It shows us that such representations are partial, but productive. Thus, not only are students considering fire from different perspectives, they are also contrasting different forms for representing the process.

TABLE 3. Student Perceptions of the Unit

STUDENT (GRADE)	WHAT DID YOU LEARN?	WHAT WAS YOUR PROJECT ABOUT?
Kathy (4)	The smaller the beaker and the taller the candle, the less time the candle burns.	Volcanoes
Sam (4)	Fire needs oxygen.	Chicago Fire
Carolyn (4)	Candles run out of oxygen when put under a jar.	Volcanoes
Jonathon (4)	The bigger candle goes out first because it needs more oxygen.	The Chicago Fire
Kate (5)	Larger beakers have more air.	_____
Jeremy (5)	Larger beakers have more oxygen.	Careers
Colin (5)	Fire needs oxygen. Bigger beakers have more oxygen.	History of Fire How early people used fire
Colin (6)	Candles need oxygen to burn. Bigger beakers hold more oxygen.	Disasters St. John's fire disaster
Laurene (6)	With more candles, the flame goes out faster. Bigger beakers have more oxygen.	Disasters How fires are put out How sprinklers work
Katherine (6)	The flame burns longer in a bigger jar.	History of Fire
Paul (6)	The candle lasts longer in a bigger beaker because there is more oxygen.	History of Fire
Michelle (6)	Candles burn longer in a beaker because there is more oxygen.	Careers Oil-Well Fire Fighter, Red Adair

The students responded strongly to these features of the computer and to the comparison between what the computer "knows" and what they know, both in the lessons in the classroom and when interviewed. Having access to a computer made it easy to pursue this element of the unit. Although the virtues we have been considering are those of simulation itself, the computer provides a powerful tool for doing simulations. This is so because of its computational and graphical capacities, not to mention the fact that students are able to control how they explore the simulated system.

On a more mundane level, the computer simulates the scientific experiment and allows students to gather data and see that data represented, even printed, for them to take back to their desk. Such features allow stress to be placed on scientific thinking skills and on the problem of handling data. The computer interacts with students as well as ordering and representing information.

These computer features allowed students to see how science and mathematics were related. As well, these features encouraged the students to think about how they themselves know things at all. This provides a link to their study of myths and the history of fire in language arts and social studies.

INTEGRATION WITH CLASSROOM ROUTINES

It is critical that teachers be able to use computers without having to radically alter their routine approaches to teaching. These routine approaches reflect their response to complex and

enduring problems in school life. The computer is only one of the elements in this complex array. How did the computer fit into the routines of the school?

First, access to the computer lab is a scarce resource. To cope with this problem, Mr. Beckwith assigned time to teachers to use the lab. The teachers had to plan around this assigned time. When the teachers needed access to the lab was determined by the unit design and by other teaching plans, as well as by the pattern of whole- or part-class withdrawal common in the junior division in the school.

The lab contained 10 computers, but each class had about 30 students. In the case of the Grade 4/5s, Mrs. Peters decided to do the unit with the Grade 4s during the time when they had social and environmental studies with her, and the Grade 5s had SES with their French teacher. In this way, students could work in pairs or on their own in the lab, and the problem of overcrowding in the computer lab was avoided. All of the Grade 5/6s did the unit in a variety of time slots, but the time when they were able to go to the lab was constrained by the existing schedule for their withdrawal to other activities (music and French, for example).

The teachers had to be very flexible in responding to a complex schedule of routine withdrawals in the school, not to mention special occasions and last-minute rearrangements. Units typically depend on access to resources, like computer labs, at the right time, in order that follow-up activity, which may in-

volve borrowed equipment, can take place. Integrated units make the process even more complex because a greater diversity of resources and more intricate scheduling may be involved. Teacher control of lab access is important, especially when lab work emerges out of ongoing classroom activity.

During the two-week time the unit was taught, access to the computer lab occurred as scheduled, but it was clear that there were many aspects of school routine which could easily have disrupted the schedule. The requirement of flexible response on the part of the teachers is significant. They were able to handle this demand smoothly, no doubt because of their past experience.

Routines are a vital part of classroom management. Teachers have their preferred ways of conducting classroom activities and the computer is simply another element to be incorporated into those routines. With whole- or part-class access to a computer lab, computer integration is less difficult; the class simply moves to another room where students usually work in groups of two or three. However, students may not like this way of working, and teachers may prefer to have students working on their own, or in the classroom, rather than in a lab. The way that students and teachers react to group work on computers depends on earlier experience of group work in the classroom. Clearly, many important questions revolve around group work issues, as well as class withdrawal to a lab.

FLAME LIFE is a curriculum-specific program whose use is likely to require considerable adjustment to pre-existing content

and methods. It requires even more adjustment when organised within an integrated framework, as is the case here. The teachers on the team contributed a considerable amount of their time and classroom time, also their expertise in teaching in junior division classrooms, in order that the unit could be conducted in an integrated fashion. They made considerable adjustments in order to make time for the unit as a whole and for the computer-based learning. The unit exemplifies the demands that a curriculum-specific program makes on teacher time. Such demands were a salient part of the teachers' experience with the unit.

Mr. Rawley said: "The actual working through the planning time (was most demanding) we spent half a day (on two occasions) talking it through." Mrs. Peters found her own preparation time was considerable:

> "Finding the stories, the exercise for the kids to do, and making up the spelling lists. In the math part it was the graphing skills. I madly looked for things the kids could use, but I found just one good book."

They said that the actual teaching of the unit was less demanding than the design process. Although considerable effort went into pulling the unit together, the teachers felt it paid off in the teaching phase. As Mrs. Peters said: "Very little preparation was required day to day because everything had been set up before." Similarly, Mr. Rawley said: "The success of it is that it was well-planned at the front end."

There were extra demands stemming from the activity basis of the unit. Equipment had to be found, graph paper of the right size located, worksheet dittos had to be prepared, and class results had to be charted. These activities took time. It was important that each teacher preview the computer program thoroughly. The books and films that came from the Teachers' Centre of the school board were appreciated, the teachers said, because having that support made the design phase less onerous.

There were the uncertainties associated with high levels of student activity and self-directed work. As Mr. Rawley put it: "Because you allowed them the time to go at it and you weren't at the front directing, you hoped they were making good use of their time." Mrs. Peters thought that it would be easier to supervise students if the computer activity had been done in the classroom.

Having access to a computer lab made it easier to complete the computer-based work in a short period of time and thus to be prepared to go ahead as a class to the next part of the work. With only one or two computers in each room this would have been much more difficult, yet the teachers felt it could be done. Mr. Rawley said he would set up two activity centres, as well as have two computer centres. Part of the class would work on graphing, part on research, and two groups would do the experiments on the computers. Mrs. Peters had a similar plan in mind:

> "On the day of the computer lab give the children a 15-20 minute time slot on the computer during which time they could do that particular aspect of the experiment on the computer. It would be easier to supervise them."

Mr. Rawley suggested some changes for the future:

> "This is a class of high ability. With another class you might have them do an experiment and go to the computer, then do another experiment and go to the computer. With this class they just did the one experiment and then kept going to the computer."

The experiment supplied an interest that the computer lacked in the sense that the experiment appealed to all of the senses. We have noted already that students enjoyed the real thing. Mr. Rawley is suggesting that the real thing provides a stimulating context for follow-up on the computer.

Discussion

Mr. Rawley's comments provide a useful point of departure for a discussion of our experience of planning and teaching this unit. Of course, it is not always easy to do experiments, such as having students at the junior level burn candles. There are problems of space, equipment, class management, and safety which have to be overcome. Nevertheless, it is clear that in this case the computer is no substitute for the real thing. However, the real thing can be supplemented by computer activity.

In order to integrate the computer and the real thing, it is important that students understand what underlies their work in both settings. This requires that discussion of the themes occur with the class. Work should be organized so that the transition from computer to classroom work is meaningful to students. This is both a curricular issue and a management issue. In view of the demands of integrated units, it is not surprising that the design phase of the unit is so demanding. It is here that these problems

have to be anticipated. The importance of transition in an integrated unit, and especially one involving the computer, points up the importance of well-designed individual seat and group work. Somehow the classroom teacher has to incorporate software into existing classroom routines in such a way that the move to the computer makes sense. Usually it is not designed by the teacher and is based on assumptions about available classroom support which may be more or less valid.

These comments apply to curriculum-related software, where a productive alliance is to be formed between the software and the work of the classroom. Given the time it takes teachers to become familiar with software and their need to know what assumptions are built into the software, it is clear that documentation is a major element of effective lessonware design. To paraphrase: "No lessonware is an island unto itself."

The curricular and classroom-routine aspects of integration we have been considering do not exist in isolation from each other, as we hope the preceding discussion makes clear. Finding integrating subthemes which enable children to make sense of their experiments is crucial. It is those subthemes that help teachers and students make the transition from one subject to another, and from one activity to another. Finding these subthemes and working them out, through careful selection of materials and activities, is an arduous task to which Mrs. Peters and Mr. Rawley made major contributions.

Resource acquisition and analysis are much more complex than their standard representation in the literature of curriculum design. As we found, there is a back-and-forth process in which analysis of available resources leads to ideas for what else is needed and why some resources are inadequate. The process allows the development of subthemes which are discovered in the available materials and not imposed on them. This is all the more reason that lessonware designers take the time to document their intent and resource assumptions. Then the teams working on integrated units can profit from the ideas of lessonware given in the design process described above.

CHAPTER 4: SIGNIFICANCE OF THE STUDY:

QUESTIONS ABOUT CHANGE

MAKING SENSE OF PRACTICE

One broad theme will be considered in this summary chapter: how might teachers and students understand their experience in new and more productive ways, and thus change for the better what they do? We must find the contribution that information technology can make to this process. To develop this theme we will explore the idea that computers provide a new resource for exploring our everyday approach to tasks. Thinking about those tasks with and without computers is one way to see more clearly why we do things as we do. We also can see how new technologies could help us do those things better.

There is little doubt that we tend to develop settled ways of making sense of our experiences, and that those ways endure as long as they are satisfying. New, dissonant experiences have a tendency to unsettle our preconceptions and make us think again. Computers as tools for teaching have this potential for teachers; as tools for learning they have a similar potential for students. What are these potentials? We have had glimpses of them in previous chapters and draw them together now in a list:

Teachers using computers to express important things about their practice by taking the computer as a symbol of their commitments:

> "What am I trying to say to my students about myself and my subject?"

Teachers rethinking what they teach:

> "Are some aspects of this subject more important than I had thought and others less?"

Teachers reconsidering their role in helping students learn:

> "Might I sometimes be less directive and more facilitative?"

Students confronting their own preconceptions in a critical way:

> "Do things really behave in ways that I expect?"

Students working with each other in unfamiliar ways:

> "Might the problem need the perspective of more than one person; more than one way of looking at things?"

We have seen also the potential of computers in the classroom. They can:

- perform complex transformations of information rapidly
- offer multiple representations of information
- let students probe the limits of systems in order to understand their structure
- help students get to the bottom of things
- form bridges between different but related things that are being learned
- create traces of what was done and store the results of accumulated effort
- be patient, personal, and prepared to work
- provide a focal point for collaboration

Computer simulation is an important learning tool for achieving such potentials. Computers can help make simulation a powerful process in teaching for reasons other than those usually

advanced in support of computers in education. While learning how to program might be an exercise in learning how to think, because it is assumed that thinking resembles what computers do, we also want to consider that computers are important because they help us confront our experience--to make sense of it. Computers are tools for signification as well as tools for thinking. From that point of view, computers in general, and simulations in particular, become very important for learning about what things mean to us.

There are quite different ways to think about the process of change itself and the process of children's learning. Both of these areas of inquiry, which are highly relevant to the role computers play in education, would profit from a focus on the meaning of human action, rather than only on the thought processes it entails. Change, for example, is a process of reassigning meaning to practice, as well as actually adopting new practices. It is not only the cognitive capacities--competence, if you like--of practitioners that are at issue in developing new practices, but the making sense of their practice in new ways. When we look at change this way and when we consider the potential of computers in education, it is clear that there is more at stake for teachers than learning new routines.

Similarly, it is not only the cognitive capacity of students that is at issue when they tackle problems posed to them in science. They also are being asked to see the world in new ways--to assign meanings to things in a different way. We shall consider the role of computers in coming to know the world in new

and more productive ways. First, however, we must consider in detail why it is important to focus on the meaning of practice as a basis for thinking about changes in practice. It should be clear that both the practice of the teacher and the practice of the learner are at issue here.

Teaching has often been studied as an instrumental activity in which learners learn from teachers, who thus are instruments of learning. Teaching is also an expressive activity in which teachers say things about themselves, about school subjects, and about their relationships to students through their teaching. It is quite likely that the expressive messages which accompany the pursuit of learning objectives contribute as much to an educationally valuable interchange as do the instrumental activities themselves (Jackson 1986).

What teaching means both to the teacher and the student can be framed in terms of the rules which are not programs for action. They are the ideas which constitute the practice we are considering (Geertz 1979; Taylor 1979). Without the rules there would be no practice to consider.

Consider the Grade 5 class we watched giving group reports on the Fire projects to the rest of the class. Each group followed a careful sequence of steps; each group went through the same steps. This is a complex and patterned process in which students participate in a form of classroom life which allows each to play a satisfying role. It allows for personal "glory", but minimizes risk of "loss of face". Much the same could be said for other practices associated with learning. A student who

repeatedly enters the same value for a variable in FLAME LIFE is testing the system for meaning: Is this a system I can trust? Is it stable in some way? These repeated numbers, seen from the programmer's point of view, at first make no sense. The point is that the student has brought to the program a set of concerns that the programmer had not considered. They have to do with the meaning of the activities the student engages in. It is those meanings we need to understand.

How do we come to express our meaning? What important vocabulary can we call on? Making sense of these expressive elements of teaching is as yet not a major strand in research on teaching, but it should be. Without it we are hard pressed to understand how students and teachers approach computers.

What practices mean is central in understanding how new ideas will fare in school, because meaning lies at the heart of professional induction, and meaning lies at the heart of school reform. To understand the practices of teachers and students is to "find a context within which they can be intelligibly described" (Geertz 1973, p. 14.).

Students bring their own ideas about how things work when they encounter science activities in the classroom. They do not come to these experiences empty-headed; they have ways of attaching significance to events. The computers offer them ways of testing their ideas about what things signify, even ways of changing their ideas. The same is true of teachers and computers.

Teachers and students bring ideas to school about how classrooms should work. These ideas affect their responses to computer-based learning. Thus, in the case of the Fire Unit, it is critical to understand how teachers and students conduct the "business" of junior division classrooms as a microcosm of school society. Junior division teachers face challenges associated with work in that division. They meet those challenges in ways they find effective. How these teachers, and teachers in general, make sense of such curriculum forms as integrated units, and such resources as computer-based learning, must be understood if we are to see where studies like this one might lead. The nature of learning itself cannot guide future practice, because the intentions of teachers give meaning to classroom practices. Accounts of teacher perceptions of their practice are thus a vital source of guidance. These accounts help us understand why classrooms are the way they are, and why computers are used in this or that way. In the following section, we look at how computers can contribute to school change.

COMPUTERS AND THE PROCESS OF CHANGE

In the study of the Fire Unit, seeing the context in which teachers work helps us understand their computer experiences. Their experience with computer-based learning calls into question how much time they as junior teachers can devote to redesigning existing routines which already work well in the overall structure of the elementary school. These routines perform complex functions: they allow the teachers to express themselves to students as effective, capable people. Without understanding

these routines and their meaning, we cannot make sense of the impact of the computer on their classroom life.

The need for preparation and the time-consuming search for materials for integrated teaching and to support computer-based work are important matters. The assumed rate at which these matters could be arranged for teaching is called into question by the demands of the computer for preview of software and the designs of supporting structures. The significance of time allocation, for example, is called into question by the new practices. How such questions are resolved tells us what is important and what is not so important, in the day-to-day practices of the school. The computer makes many demands. Teachers have to decide what those demands mean for them in terms of how they do their work.

Even if we understand the teachers better as a result of such an analysis, how can such a process help teachers improve their practice? Is this analysis simply a way of rationalizing what exists--an essentially conservative process?

If teachers are challenged to think about their own practices in terms of their meaning, their value, and in relation to the meaning of other practices which challenge the validity of what exists, might teachers improve?

Coming into contact with coherent and well-articulated practices, purposes, and values different from one's own is healthy. This is especially true when those involved begin to learn more about what their own practices mean, and what values

are expressed in the activities of that practice (Olson 1985; Olson and Eaton 1986; Olson and Eaton 1987).

The most valuable ideas do not necessarily emerge from the culture of temporary innovative systems, or state educational bureaucracies, or, for that matter, teacher groups. Indeed Schon (1983) suggests that innovators who cling to a research-based culture have underestimated the wisdom of the values of practitioners. That is because they have overestimated the utility of scientific research for improved practice, and underestimated the knowledge that exists in the culture of professionals--their knowledge and skill (Elliott 1985).

Much attention has been given to understanding how software can work in psychological terms; the same thought ought to be given to how software can work in pedagogical terms. Teachers are best placed to tell about that. They know how the classroom itself is constituted by the routines of their practice. They have knowledge and skill which needs to be probed as part of understanding how new technologies can contribute to better pedagogy, thus to better learning.

The knowledge and skill which we must heed can be clearly seen in the case of Mrs. Peters and Mr. Rawley. Bringing together the resources required to integrate computers in the curriculum and organizing time in such a way that each element of the plan receives its due, is a complex task. It is made more difficult by the school schedule of activities within which these teachers have to fit; this includes the schedule of access to

computer labs. But those demands challenged these teachers to reconsider their everyday routines--not in order to abandon them, but to improve them.

The many complex routines that go into bringing materials, time, and energy together sustain the schooling process. The intervention of researchers as co-planners simply trades on those routines which, if they had to be invented from scratch, would take the integration of computers in the school into another magnitude of complexity. We outsiders could not invent such routines in any event, for we do not fully understand how life in junior classrooms is constituted. But the value of those routines is subject to re-appraisal in the light of experience with the Fire Unit and the inquiry processes it involved. Teachers have to consider whether or not existing routines do stimulate inquiry--they have to consider the value of inquiry as a learning process in relation to what they value as expressed in existing routines. They have to consider how well units like that on Fire help them achieve their purposes. Not only is the learning process to be evaluated, but the role of science activities in the junior curriculum is at issue. Do students do enough in that area? Does that area matter? These are questions which emerge from the dialogue between innovative practices and existing routines.

We cannot understand the significance of innovation unless we understand the meaning of existing practices, and thus the way innovative and existing practices interact. The assumption that we can bolt on this or that piece of software in the classroom

trivializes the complexity of practice and the difficulty of change. It is a not-so-subtle way of placing the onus for improved practice on individual teachers while ignoring the reasons why current practices exist--ignoring what they mean in the context of school life. There has to be dialogue between the ideas of software and the ideas of existing classroom practices.

If the promise of computers is to be fulfilled, teachers must be able to use computers in forms of teaching which, although often difficult, are within their capabilities, but not often tried. Helping students interpret experience, for example, is part of what teachers have always done. The computer permits a rich exploration of experience and demands a high level of competence from the teacher so that students might fully benefit from computer-based learning. Experience with computers challenges teachers to re-appraise their practice--to consider if they indeed are challenging their students.

It is here that talk of student-and-teacher conceptual change join. Through the stimulating role of the computer and exemplary software, teachers are called upon to exercise, at a high level, skills which they already possess in varying degrees.

In the present study, students had opportunities to explore not only what they were learning, but how they were learning. The computer gave them a chance to test their own ideas. The team planned experiences with this idea in mind. Multiple perspectives on fire were studied, and students were asked not only to test their ideas about combustion against the phenomenon itself (actual and simulated), but against other ways of thinking

about fire. They were asked to know how they know by thinking about how the computer "knows", but also how early humankind expressed its beliefs through myths.

Planning units like Fire takes considerable time and demands complex scheduling and resources. Teachers need time to plan such units and they need access to complex resources. Access to computer labs, for example, has to be dedicated to the planning of the unit, rather than vice versa. A critical question here for school policy is the deployment and control of computer resources. How can curriculum-planned computer use be managed so that access supports ongoing classroom activity? Implied here is substantial advanced planning and negotiation of access and deployment. The integration of computer-based resources in the curriculum is a difficult task, and this study illustrates the level of advanced planning required to do it (as Appendix 1 indicates). Such planning presupposes forms of staff interaction in which teachers are able to negotiate and collaborate. These are questions that schools have to deal with in making the best use of scarce resources. When computers serve curricular plans, access has to be negotiated rather than imposed. Support for unit planning must take into account the particular demands of junior level teaching. This includes the complex patterns of student movement in the school, the need for non-print resources, and increasingly complex and diverse subject-specific curriculum demands (for example, the recent science initiatives from the Ministry of Education). Given these demands, teachers are called to re-evaluate existing routines and resources in relation to the

demands of computer-based learning--to find an accomodation between the essential values of the former and the potential of the latter. Teachers are challenged to reconsider what they value.

Reconsidering values is at the heart of change. As students reflect on their experience, they come to see how they think in a new light. So it is for teachers. As the potential of computer-based learning becomes apparent in the experience of teachers, the value of existing routines also becomes more apparent, and both routines and computer-based learning designs change as each is influenced by the other. It is a process of dialogue between people who embody their ideas in innovations (such as software) and teachers who express their ideas in their teaching routines. Making the most of dialogue is the key to in-school and system-wide professional development and to the design of valuable software. Central to the success of these changes is a fuller understanding of the nature and value of the existing classroom routines that constitute schooling.

REFERENCES

Driver, R., and Bell, B. "Students' Thinking and the Learning of Science: A Constructivist View." School Science Review 67 (240) (1986), pp. 443-456.

Elliott, J. "Some Key Concepts underlying Teachers' Evaluation of Innovation." In P. Tamir, ed. The Role of Evaluators in Curriculum Development. London: Croom-Helm, 1985.

Geertz, C. The Interpretation of Cultures. New York: Basic Books, 1973.

_____. "From the Native's Point of View: On the Nature of Anthropological Understanding." In P. Rabinow and W. Sullivan, eds. Interpretive Social Science. Berkeley: University of California Press, 1979.

Jackson, P. On the Place of Narration in Teaching. Chicago: Benton Centre for Curriculum and Instruction. Xerox, 1986.

Olson, J. "Changing our Ideas about Change." Canadian Journal of Education 10 (1985), pp. 294-308.

_____. and Eaton, S. Case Studies of Microcomputers in the Classroom. Toronto: Ministry of Education, Ontario, 1986.

_____. and Eaton, S. "Curriculum Change and the Classroom Order." In J. Calderhead, ed. Exploring Teacher Thinking. London: Cassell, 1987.

Ontario. Ministry of Education. Education in the Primary and Junior Divisions. Toronto: Ministry of Education, Ontario, 1975.

Schon, D. The Reflective Practitioner: How Professionals Think in Action. New York: Basic Books, 1983.

Taylor, C. "Interpretation and the Sciences of Man." In P. Rabinow and W. Sullivan, eds. Interpretive Social Science. Berkeley: University of California Press, 1979.

APPENDIX 1: PLANNING, DESIGNING, AND TEACHING THE UNIT

The Chronology

In this section we give a chronological description of the research activities which were organized into three phases: planning, designing, and teaching the unit. The data were collected over a period of five months spanning October 1986 to February 1987.

PLANNING PHASE (October-November 1986)

During the planning phase the basis of collaboration between researchers and staff was established through two meetings and two interviews which explored the teachers' general orientation.

30 October, 1986: Meeting # 1

Researchers met with staff to discuss, in general terms, ideas for the proposed integrated social and environmental studies unit on the theme of fire. It was agreed that both classes would do the science experiment in the classroom, followed by seatwork related to observations of the experiment and graphing activities. The experiment would be followed by several FLAME LIFE simulations in the computer centre, preceded and followed by seatwork involving graphing, predicting, and interpretation skills. In the context of the science experiment, Mr. Rawley expressed reservations about "open flame in the classroom and burning wax" which could pose a danger unless the experiment were teacher-controlled.

While each class would have sessions involving social and environmental studies and language arts, it was agreed that Mr. Rawley would put a heavier emphasis on the SES component, while Mrs. Peters would spend more time on language arts. Mr. Rawley was interested in the history and uses of fire, especially in the context of early settlers in Canada, and he suggested that his students would research projects and make group presentations. Mrs. Peters expressed an interest in exploring myths about fire: North American Indian and Inuit myths, as well as the classic Greek legends. Her students would write their own fire myths then enter, edit, and print them on the computer. Researchers suggested wrapping up the unit with a "fairlike" day of events to bring together all the activities and both classes. However, both teachers preferred an independent style of working.

Notes were taken at this meeting. The notes were a record of the meeting and they constituted an agenda for further action. It was agreed that the research team would provide resources in terms of books, films and videos on the theme of fire, and the necessary equipment for the science experiment. At this point, both teachers were heavily involved in other school activities.

12 November, 1986: Meeting # 2

At this meeting we responded to teacher concerns about our data gathering by developing mutually agreeable procedures.

14 November, 1986: Interview # 1

Mrs. Peters was interviewed concerning her general orientation toward teaching, learning, and computers. On the basis of this, and a subsequent interview (see Appendix 2.A), a profile of Mrs. Peters was composed.

28 November, 1986: Interview # 2

A similar interview was conducted with Mr. Rawley.

Discussion:

By the end of this phase we had established a collaborative working relationship with the staff, and had introduced the study unit and its various components.

DESIGN PHASE (December 1986-January 1987)

Two meetings were held during this phase in which researchers and staff collectively designed the study unit, scheduled the activities into a logical sequence, and selected learning resources. Between meetings, a letter was sent to the staff confirming arrangements and enclosing worksheets and teaching notes. The researchers continued to work as participant observers throughout the design phase.

8 December, 1986: Meeting # 3

We opened the meeting by discussing the study unit as a vehicle

for exploring our interest in what children think about fire. We also discussed the process of integrating the computer into the curriculum and classroom routines. The teachers were interested in the motivating power of computers. "They excite students, just the fact they're in the school," said Mr. Rawley. Mrs. Peters observed that she had seen this excitement turn into frustration when the equipment broke down, or when her students had gone to the computer centre and found another class already there. We agreed that these interests would be documented.

At this meeting we rehearsed the science experiment in order to modify the procedures for the classroom. The experiment involved burning candles under three different-sized beakers and timing the life of the flame. We floated birthday candles on styrofoam in water, lit a candle with matches, then covered the candle with a beaker and recorded the burn time. We repeated this process several times using different-sized beakers. Several matches gave off phosphorus sparks, so we decided it would be safer in the classroom to provide one master candle from which students could light the smaller candles. We agreed that students would work in groups of three: one to light the candle, one to time the flame life, and one to record the time on a chart.

After rehearsing the experiment we discussed the follow-up math activities which involved finding an average from charts, and preparing a line graph from the results of the experiment.

For the resource-based activities we previewed the books, films, and videos collected by the researchers so the staff could

make selections. We viewed films and videos on combustion, fighting forest fires, fire prevention techniques, and the careers of fire fighters and welders. The selection of books covered myths about the origin of fire; historical uses of fire; fire disasters; and methods of preventing and fighting fires.

We discussed ways to link the four elements of science, mathematics, language arts, and social and environmental studies with each other and with the computer: how to integrate FLAME LIFE simulations with the science and math concepts, and how to use the word-processing capabilities of the ICON for students' stories and myths about fire.

Practical details involving access to the computer centre and scheduling the unit into existing timetables, were also blocked out. Both teachers expressed a preference for working separately with their own classes.

It was agreed that the researchers would make up the science worksheets and provide materials for the science and resource-based activities. The teachers agreed to draw up a firm teaching timetable for the unit to bring to the next meeting.

9 January, 1987: Letter # 1

Prior to the Christmas holidays, a school-wide schedule of access to the computer centre was established. It therefore became necessary to plan the sequencing of the unit around the times that the computer centre would be available for each class involved in the study. In response to this change, we sent a

letter to the teachers early in 1987 requesting that they bring a firm schedule of when they would have access to the computer centre, and when they planned to do the science experiment. We enclosed the worksheets and teaching notes to accompany the science and graphing activities.

16 January, 1987: Meeting # 4

At this meeting we constructed a detailed plan for the sequencing of the entire unit. There were two scheduling constraints for Mrs. Peters' class: limited access to the computer centre, and withdrawal of Grade 5 students every day for French instruction in social and environmental studies (SES). Having access to the computer centre only twice a week determined when the math activities could take place: math concepts had to be introduced before proceeding with FLAME LIFE simulations. To overcome the second constraint -- withdrawal of Grade 5 students -- Mrs. Peters decided that only her Grade 4s would participate in the study. At this meeting we designed timetables for both classes (see tables 1 and 2).

We worked through the graphing activities and the worksheets (see Appendix 2.D). Mrs. Peters suggested we hook up the Sony television set to the computer in the classroom so that during the graphing follow-up to the experiment, students could feed their burn time numbers into the computer which would then display a graph on the big screen for the whole class to see. Students could then compare their graphs with the one produced by the computer.

At this meeting the staff chose the media resources they wanted to use, and the whole group decided what each person's responsibilities would be during the teaching phase. It was agreed that the researchers would videotape key parts of the study unit.

Discussion:

During the design phase we worked out in detail the sequencing of the unit, the resources to be used, and the work we expected the students to complete. The role of the researchers as participant observers during the teaching phase was established.

TEACHING PHASE (January-February 1987)

Mrs. Peters and Mr. Rawley taught most of the unit. The researchers participated in parts of the teaching phase by teaching, observing, questioning, videotaping, and interviewing students. The description of classroom events that follows is organized chronologically, and is documented separately for each class. See tables 1 and 2 for the Fire Unit plan. Descriptions of what occurred during the absence of the researchers were provided by staff in subsequent interviews (interviews # 3 and # 4). These two interviews were part of the teaching phase, as were interviews conducted with students concerning their experience of the unit (interview # 5).

GRADE 4 FIRE UNIT DESCRIPTION

(19 January-13 February,1987)

Monday Jan.19 **LANGUAGE ARTS # 1**
SPELLING

Mrs. Peters wrote a list of 18 words on the blackboard that were related to the Fire Unit; for example, "oxygen", "beaker", "simulation". Students copied out the words in alphabetical order, then arranged them in a crossword pattern.

Monday Jan.19 **SOCIAL AND ENVIRONMENTAL STUDIES # 1**
INTRODUCING PROJECT TOPICS

This lesson introduced the class to different aspects of the fire theme. Students were asked to volunteer ideas and situations related to fire. Mrs. Peters and her students categorized these ideas into a flowchart which the teacher drew on the blackboard. The flowchart listed topics, such as fire control and uses, disasters and careers.

Tuesday Jan.20 **SCIENCE # 1**
EXPLORE FLAME LIFE

Students spent this period in the computer centre in an unstructured exploration of FLAME LIFE. They were asked to record on paper, in chart form, how long candles burn under different-sized beakers.

Tuesday MATH # 1
Jan.20 CHARTS & GRAPHS

Using the charts they had made above, students discussed what they had learned about burning candles under different-sized beakers. Mrs. Peters made a large chart which listed all their results, and she circled the shortest and longest burn times. The whole class then watched a 15-minute video about graphing.

Tuesday LANGUAGE ARTS # 2
Jan.20 SILENT READING

Each student had a copy of an Indian myth about fire which had been reproduced from a reader. Students silently read the story.

Wed. SCIENCE # 2
Jan.21 EXPERIMENT

The research team participated in this session by conducting the experiment and follow-up discussion, and videotaping the lesson. Mrs. Peters assisted students who were working in groups of three. Each group made a chart listing the results of three trials of three sizes of beakers. Students answered the questions in their worksheets (see Appendix 2.D: EXPERIMENT # 1).

Wed. MATH # 2
Jan.21 AVERAGING

Researchers videotaped this lesson and led a discussion on averaging. We drew a large chart on the board and recorded results from the charts students had made during the experiment. Then we discussed how to obtain

an average burn time -- a class average -- for each size of beaker.

Thursday LANGUAGE ARTS # 3
Jan.22 READING

Students read aloud the Indian fire myth (see L.A. # 2 above) and answered comprehension questions in their workbooks.

Thursday SOCIAL AND ENVIRONMENTAL STUDIES # 2
Jan.22 CHOOSING PROJECT TOPICS

Students reviewed the flowchart of fire themes (see SES # 1 above) and looked through all the books on display in order to choose their topics for class presentations.

Monday LANGUAGE ARTS # 4
Jan.26 SPELLING

Students added prefixes and suffixes to the spelling words previously introduced in L.A. # 1.

Monday LANGUAGE ARTS # 5
Jan.26 READING

Students read aloud a story from a reader about a fire destroying a village.

Monday MATH # 3
Jan.26 GRAPHING

Students made graphs using three beaker sizes from the experiment, depicting the relationship between beaker size and flame life. On the basis of their graphs, they estimated burn times for beakers of different sizes from what they used in the experiment. They wrote their predictions on their worksheets (see Appendix 2.D:

EXPERIMENT # 2).

Monday Jan.26 — SOCIAL AND ENVIRONMENTAL STUDIES # 3
FIGHTING FOREST FIRES

The class watched a 15-minute film about a forest fire. It was a visually powerful documentary with no narration -- only the sound of burning wood and falling trees. This was followed by a class discussion of fire-fighting techniques and how they had changed over time.

Tuesday Jan.27 — SCIENCE # 3
FLAME LIFE SIMULATION: VARIABLE -- BEAKER SIZE

Students took the worksheets from MATH # 3 lesson to the computer centre where they did a simulation of the experiment involving changing the size of beakers. They answered the remaining worksheet questions comparing their burn-time guesses with computer results (see Appendix 2.D: EXPERIMENT # 2). This session was videotaped. Researchers and staff worked with students in groups of one or two at the computer.

Tuesday Jan.27 — MATH # 4
GRAPHING/PREDICTING

Having done the experiment and the simulation of burning candles under different-sized beakers, the researchers asked students to compare the two experiences. We asked, "Who is right, the computer or the live experiment, and why?" This discussion was videotaped. Students also compared their worksheet guesses of burn times, and the graphs they had made, with the burn times and graphs produced by the computer.

Tuesday Jan.27 — SOCIAL AND ENVIRONMENTAL STUDIES # 4
PROJECT ACTIVITIES

Students worked independently on their projects -- in the classroom, library, or hall (see Appendix 2.E which lists project topics).

Wed. Jan.28 — COMPILING BOOKLETS

Students started compiling their booklets containing all the written work produced for the Fire Unit (see Appendix 2.F).

Wed. Jan.28 — SOCIAL AND ENVIRONMENTAL STUDIES # 5
PROJECT ACTIVITIES

Students continued to work independently on projects.

Thursday Jan.29 — LANGUAGE ARTS # 6
READING COMPREHENSION

Based on the story read in L.A. # 3, students completed comprehension exercises in their Fire booklets.

Thursday Jan.29 — SOCIAL AND ENVIRONMENTAL STUDIES # 6
PROJECT ACTIVITIES

Students completed research and preparation for the project presentations.

Friday Jan.30 — SCIENCE # 4
FLAME LIFE SIMULATION: VARIABLE -- NUMBER OF CANDLES

Before going to the computer centre, students were asked to predict what would happen if they changed the number of candles burning under one beaker (see Appendix 2.D: EXPERIMENT # 3). In the lab they did the simulation, compared the computer results with their predictions, and wrote down why they thought the flame life was

shorter when the number of candles was increased. Researchers were present to observe, assist, question students, and videotape this session, while Mrs. Peters worked with individuals and groups.

Friday Jan.30 — MATH # 5
GRAPHING

Using results from the simulation above, students drew graphs depicting the relationship between flame life and number of candles.

Monday Feb.2 — SOCIAL AND ENVIRONMENTAL STUDIES # 7
PROJECT PRESENTATIONS

Students gave their presentations (see Appendix 2.E for a list of topics). Some students memorized their speeches, while others read them; some produced graphics as illustration; one group made a model of a volcano; and another group demonstrated the making of fireworks.

Tuesday Feb.3 — SCIENCE # 5
FLAME LIFE SIMULATION: VARIABLE -- CANDLE HEIGHT

After predicting what would happen if the height of candles were changed, students did the simulation in the computer centre.

Tuesday Feb.3 — SCIENCE # 6
COMBUSTION

The class watched a 15-minute segment of a film depicting the process of combustion.

Wed. Feb.4 — LANGUAGE ARTS # 7
READING

Whole class participated in reading a story about fire.

Wed. LANGUAGE ARTS # 8
Feb.4 WRITING

Students wrote myths describing how fire came to earth.

Thursday LANGUAGE ARTS # 9
Feb.5 COMPREHENSION

The class completed comprehension exercises concerning the story about fire.

Thursday MATH # 6
Feb.5 GRAPHING

Line graphs depicting the relationship between height of candle and flame life were completed.

Thursday LANGUAGE ARTS # 10
Feb.5 SPELLING

Mrs. Peters dictated the spelling words introduced in L.A. # 1.

Friday COMPILING BOOKLETS
Feb.6

All written work and booklets on the theme of fire were completed.

Friday SOCIAL AND ENVIRONMENTAL STUDIES # 8
Feb.6 VOLCANOES

A 30-minute video about Vesuvius was screened.

Tuesday SOCIAL AND ENVIRONMENTAL STUDIES # 9
Feb.10 PROJECT PRESENTATIONS

Researchers videotaped the students giving a repeat performance of their project presentations.

GRADE 5/6 FIRE UNIT DESCRIPTION

(19 January-30 January,1987)

Monday Jan.19 — MATH # 1
GRAPHING

Mr. Rawley introduced the class to bar graphs and line graphs by drawing several examples on the board.

Monday Jan.19 — SOCIAL AND ENVIRONMENTAL STUDIES # 1
INTRODUCING FIRE THEME

The class watched a 15-minute film about forest fire. This documentary had no narration: it was a visual portrayal of the elemental power of fire. Following the film, students discussed various aspects of fire.

Tuesday Jan.20 — SCIENCE # 1
EXPERIMENT

Researchers participated in this session by conducting the experiment and follow-up discussion, and videotaping the lesson. Mr. Rawley assisted students who were working in groups of five and six. Each group made a chart listing the results of three trials of three sizes of beakers. Students answered the questions on their worksheets (see Appendix 2.D: EXPERIMENT # 1).

Tuesday Jan.20 — MATH # 2
AVERAGING

Researchers videotaped this lesson and led a discussion on averaging. We drew a large chart on the board and recorded results from the charts students had made during the experiment. Then we discussed how to obtain

an average burn time -- a class average -- for each size of beaker.

Wed. Jan.21 — SOCIAL AND ENVIRONMENTAL STUDIES # 2
CHOOSING PROJECT TOPICS

Based on the discussion in SES # 1, four major themes emerged: history of fire, disasters, controls and uses, and careers. Students chose which theme they wanted to research: there were six or seven students in each group.

Wed. Jan.21 — SCIENCE # 2
EXPLORE FLAME LIFE

Students spent this period in the computer centre in an unstructured exploration of FLAME LIFE. They were asked to record on paper, in chart form, how long candles burn under different-sized beakers. Mr. Rawley and the researchers worked with students in groups of two and three. This session was videotaped.

Wed. Jan.21 — MATH # 3
CHARTS/GRAPHS

Using the charts they had made above, students discussed what they had learned about burning candles under different-sized beakers. Then they made graphs using the three beaker sizes from the experiment, depicting the relationship between beaker size and flame life. On the basis of their graphs, they estimated burn times for beakers of different sizes from those used in the experiment. They wrote their predictions on their work-sheets (see Appendix 2.D: EXPERIMENT # 2).

Thursday SCIENCE # 3
Jan.22 FLAME LIFE SIMULATION: VARIABLE -- BEAKER SIZE

Students took the worksheets from MATH # 3 lesson to the computer centre where they did a simulation of the experiment involving changing the size of beakers. They answered the remaining worksheet questions comparing their burn time guesses with computer results (see Appendix 2.D: EXPERIMENT # 2). This session was videotaped. Researchers and staff worked with students in groups of two or three.

Thursday MATH # 4
Jan.22 GRAPHING

Having done the experiment and the simulation of burning candles under different-sized beakers, students were asked to compare the two experiences. They compared the graphs they made from their experiment results, with the graphs produced by the computer.

Monday LANGUAGE ARTS # 1
Jan.26 SPELLING

Mr. Rawley wrote on the board words that students would need in their study of fire; for example, "combustion", "ignition", "oxygen". Students copied out the words, and then they orally made up sentences incorporating the new words.

Monday LANGUAGE ARTS # 2
Jan.26 COMPOSITION

Students started to write their accounts of the Fire Unit.

Tuesday SCIENCE # 4
Jan.27 FLAME LIFE SIMULATION: VARIABLE -- NUMBER OF CANDLES

Before going to the computer centre, students were asked to predict what would happen if they increased the number of candles burning under one beaker (see Appendix 2.D: EXPERIMENT # 3). In the lab they did the simulation, compared the computer results with their predictions, and wrote down why they thought the flame life was shorter when the number of candles was increased. Researchers were present to observe, assist, question students, and videotape this session, while Mr. Rawley worked with individuals and groups.

Tuesday MATH # 5
Jan.27 GRAPHING

The class discussed what had happened in the simulation and why. Using the results from the simulation, they drew graphs depicting the relationship between flame life and number of candles.

Tuesday SOCIAL AND ENVIRONMENTAL STUDIES # 3
Jan.27 PROJECT ACTIVITIES

Students chose topics within the four major themes: history of fire, controls and uses, disasters, and careers. They worked independently in small groups in the classroom, the library, or the empty music room. They started the process of researching topics, writing speeches, and illustrating their work on large poster boards.

Wed. Jan.28 — SOCIAL AND ENVIRONMENTAL STUDIES # 4 and # 5
PROJECT ACTIVITIES

Students continued preparing project presentations.

Wed. Jan.28 — SCIENCE # 5
FLAME LIFE SIMULATION: VARIABLE -- CANDLE HEIGHT

After guessing what would happen if the height of candles were changed, students did the simulation in the computer centre.

Thursday Jan.29 — MATH # 6
GRAPHING

Line graphs depicting the relationship between height of candle and flame life were completed.

Thursday Jan.29 — SOCIAL AND ENVIRONMENTAL STUDIES # 6
PROJECT ACTIVITIES

Students continued to work independently on their projects.

Friday Jan.30 — SOCIAL AND ENVIRONMENTAL STUDIES # 7
PROJECT ACTIVITIES

Work on the presentations was completed.

Friday Jan.30 — SOCIAL AND ENVIRONMENTAL STUDIES # 8
PROJECT PRESENTATIONS

Students gave their project presentations. There were four themes (see Appendix 2.E). Students worked in groups of six or seven. Each student spoke for two or three minutes. They stood at the front of the class holding up posters to illustrate their talks. The posters contained coloured drawings, charts, magazine cut-outs, and handwritten essays. After each group had finished, the rest of the class had an opportunity to

ask questions, and mark the group for research and presentation skills.

Tuesday LANGUAGE ARTS # 3
Feb.3 COMPOSITION

Using STORYMATE software, students entered their accounts of the Fire Unit into the computer and printed them.

Discussion:

Following the classroom activities described above, we interviewed staff and students separately concerning their experience of the unit, the role of computers in the context of the unit, and students' understanding of the process of combustion.

10 February, 1987: Interview # 3

During this interview, Mrs. Peters described the day-to-day classroom activities involved in the Fire Unit. In addition, she answered the questions which are listed in Appendix 2.B. Her comments about the Fire Unit can be found in Chapter 3.

13 February, 1987: Interview # 4

The same interview was conducted with Mr. Rawley. His thoughts about the Fire Unit are also given in Chapter 3.

17 & 18 February, 1987: Interview # 5

Twelve students were interviewed concerning their experience of the Fire Unit, their understanding of combustion, and the role of computers in helping them learn (see Appendix 2.C). The students' comments about the unit are analysed in Chapter 2.

APPENDIX 2: RESEARCH DOCUMENTS

Appendix 2.A: Preliminary Teacher Interview Schedules
Interview # 1: November 1986

Background

1. Current professional role
   .position, for how long

2. Professional training (follow-up from information sheet)
   .degrees, diplomas, certificates obtained

3. Previous experience
   .number of years, type of experience

4. Professional development
   .courses, in-service training

5. Leadership
   .i.e., development of curricula materials; organizer of committees, workshops; presentation; courses taught

6. Professional relationship within the staff
   .partnerships, collaboration

7. Professional autonomy / preference
   . independent, co-operative, directed

8. Professional time allocation

   - distribution of time with students
     .formal teaching, informal teaching, social work, evaluation, informal observation

   - distribution of time outside of class
     .planning, planning with other teachers, lesson planning, material preparation, professional development

9. Special curricula interests

Expectations and intentions

10. Attitudes to involvement (follow-up from information sheet)

11. Expectations about involvement in the project
    .your involvement, resource co-ordinator, investigators, research assistants, project co-ordinator, technical support person

12. Concerns about your involvement in project

13. Overall feelings towards the use of the ICON
    .very enthusiastic to apprehensive (rate this)

14. Feelings about your learning to use and adapt to computers
    .very enthusiastic to apprehensive (rate this)

15. Experience in using computers

16. Factors influential in decision to use computers

17. Factors influential in decision of how to use computers with your class
    .number of machines, software, Board, Ministry, private and public expectations

18. Computer use
    .teaching computers, computer literacy, games, drill and practice, problem solving, programming, graphics, simulations, past use, intended use

    - physical set-up and organization
    - activities
    - software selection
    - access
    - integration with the rest of the curriculum
    - anticipated problem areas and possible solutions in using computers

    .workload, stress, preparation

19. Use of computers for different areas of the curriculum
    .math, science, language arts, music, art, French, SES, past use, intended use

20. Resources to facilitate use
    .adequate training and support, preparation time, principal support

Effect of Computers

21. The computer's role in attaining educational objectives

22. The effect of the computer on your teaching

    -present teaching methods
    -relationships
    -workload
    -stress

23. The effect of the computer on students

    -self-esteem
    -motivation
    -discipline
    -relationships with peers
    -relationship with teacher
    -high achievers, low achievers
    -cognitive development
    -academic achievement

Interview # 2: December 1986

Although the theme of Computers, Education, and Change is addressed specifically in questions #19 and #20, this theme should be woven throughout the interview.

Teaching Process

1. Role as a teacher
   i.e., provide, encourage, motivate, organize, transmit, shape, present, observe, facilitate

2. Main focus
   i.e., child's adjustment
   logic of materials and presentation
   interaction between child and materials

3. Program goals
   i.e., nurture self-confident children
   promote skill development and knowledge acquisition
   development - cognitive, language, physical, social, emotional

4. Of the various thing a teacher does, what seems most important to you?

5. Main features of the learning environment
   i.e., flexible enriched environment
   organized structured learning environment
   freedom within logically sequenced environment

6. Arrangement and organization of classroom
   Tell why this particular set-up seems right.

Learning Process

7. How learning takes place
   .transformation of knowledge
   .diagnosis and remediation
   .learning through social interaction

8. Influences on learning
   .teacher's role in process
   .student's role
   .environment

9. Relationship between teacher and students
   .client
   .family
   .co-learner

Teaching Style

10. How would you characterize your teaching style?

11. Is your teaching style uniform across different subject areas?
    .Math
    .Language

.Science
.Music

12. Which areas do you particularly enjoy teaching?
.Math
.Language
.Science
.Music

13. Which areas give you least satisfaction? Why?
.Math
.Language
.Science
.Music

14. How do you approach the different subject areas?
.planning
.materials and learning activities
.teaching methods (instruction, guidance, peer teaching)
.evaluation (summative, formative)
-by whom
-for whom
-of what (of self, of students)
.organization and management

15. Do you make extensive use of textbooks in your teaching?
If so, in what subject areas?
.Math
.Science
.Language
.Music

Do you make extensive use of workbooks/worksheets?
If so, in what subject areas?
.Math
.Science
.Language
.Music

16. Do you make use of concrete materials in your teaching?
If so, in what areas and how?
.Math
.Science
.Language
.Music

17. How do you see the computer fitting into a material-rich methodology?

18. Are there any subjects which you think will be particularly influenced by the availability of computer technology? In what ways?

Educational Change

19. Education as a vehicle for change?
20. Computers as a vehicle for educational change?

Appendix 2.B: Followup Teacher Interview Schedule
February 1987

1. If you were to run this unit again, what would you change?

2. What aspects would require most preparation?

3. If you did not have access to the lab, but had two machines in class, how would you arrange things to do the unit?

4. What further use of the Flame Life simulation might there be?

5. How might the simulation be improved?

6. What science teaching should accompany the unit?
   What science concepts might be taught?

7. What do students get out of the unit?

8. What does the computer experience contribute?

9. What demands does it place on the students?

10. What demands does it place on you?

Appendix 2.C: Follow-up Student Interview Schedule
February 1987

Working with the Computer

1. What work do you like to do on the computer?

2. Do you like to work with someone else? Why?

3. Do you ever work in threes? How does that work?

Fire

4. What was the most interesting thing you learned about fire?

5. What did you learn from your project?

6. What did you learn from the FLAME LIFE experiment?

7. What did you learn from doing the experiment on the computer?

8. Why does a candle go out when you cover it with a jar?

9. What does a fire produce?
   What is smoke?
   What happens to the wax?
   Could I get the candle back again if I used the melted wax?

10. Why do five candles burn for less time than one in the same size of jar?

11. Does the height of the candle make a difference to how long the flame will burn when covered with a jar?

12. Would the flame of a fat Christmas candle burn as long as the flame of a birthday candle if you used the same jar?

13. Two students each put a candle under a jar. One said that her candle burned 10 seconds, the other said that his candle burned 20 seconds. Why might two people get different results even though each used one candle?

Computer and Experiment

14. What happens in the actual experiment that does not happen when you do it on the computer?

15. What could you do in the computer experiment that you could not do in the actual experiment?

16. What was it about the experiment on the computer that allowed you to make predictions?

17. What can you learn from a graph of your results?

18. If you got one result from actually doing the experiment and another when you did it on the computer, which would you believe?

EXPERIMENT # 1 NAME_____
BURNING CANDLES GRADE_____

Problem: What happens to your candle when you put a jar over it?

Procedures:

1. Put your name and grade on the sheet.

2. First find out how big your jar is.

   Our jar is _____mL; and _____mL; and _____mL.

3. Light your candle at master candle and place it on the water.

4. Place the jar over the candle. WATCH CAREFULLY WHAT HAPPENS.

5. One of you start counting and stop counting when the candle goes out.

   HOW TO COUNT: Count out loud "One kitten, two kittens, three kittens", and so on.

6. Write down how long the candle burned.

   Our candle burned____seconds; and____seconds; and____seconds.

7. Do steps 2 to 6 twice more.

Thinking About It

8. In the space below, write a few sentences describing what you SAW during the experiment:

   _____

   _____

   _____

9. What did you discover when you compared different-sized jars?:

   _____

   _____

   _____

10. Think of as many reasons as you can to explain why the candle went out:

    _____

    _____

EXPERIMENT # 2 NAME_____

USING THE COMPUTER TO STUDY BURNING CANDLES GRADE_____

Problem: What happens when you use different-sized jars?

Procedures:

1. Write your jar size and burn-time guess in the chart below.

My jar size			
My burn-time guess			
Computer says			

2. You can now check your burn-time guess using a computer program which is a model of what you did with actual candles and jars.

3. Choose the "container size" program. Enter the size of your jar (and 1 candle 20 mm long) into the program. See how long it burns. Record that time in the graph above.

4. Then enter the size of your second jar, and record the burn time.

5. Then the size of your third jar and record the burn time.

Thinking About It

6. How do your "guesses" compare with "computer says"?

_____

_____

_____

7. How would you decide which is right?

_____

_____

_____

8. What would happen to a candle if you had a really big jar over it?

_____

_____

_____

EXPERIMENT # 3 NAME_____
INCREASING THE NUMBER OF BURNING CANDLES GRADE_____

Problem: What happens when you put more candles under the jar?

YOUR GUESS _____

_____

_____

_____

Procedures:

1. You can check your guess using the computer.

2. Choose "number of candles" program. (Enter container size (500 mL) and candle height (20 mm).)

3. Keep a record of the burn time for different numbers of candles.

Number of candles	1	2	3	4	5
Burn time					

Thinking About It

4. What happened to the burn time when you increased the number of candles?

_____

_____

_____

_____

5. Why did this happen?

_____

_____

_____

_____

TEACHER NOTES

EXPERIMENT # 1: BURNING CANDLES

1. **PREPARATION:** Put a chart on the board

Size of jar	How long candle burned

(10 lines: one for each group)

2. **INTRODUCTION:**

Tell students they will be finding out what happens when a candle is put under a jar. Stress need to:
a) observe closely everything they see
b) make sure they count properly.

3. **FOLLOW-UP:**

Collect information on board. Have students discuss other results.

TEACHER NOTES

EXPERIMENT # 2: USING THE COMPUTER TO STUDY BURNING CANDLES

1. PREPARATION:

Make a graph using three different beaker sizes. Have students estimate a burn-time for three jar sizes other than those used in the experiment. Have them record the jar size they chose and their estimated burn-time on the sheet they take to the computer.

2. INTRODUCTION IN COMPUTER LAB:

a) Have students use "container size" mode. Have them enter the beaker size, number of candles (1), and candle size (say 20 mm for everyone).
b) Remind them to complete the sheets before they leave the lab.

3. FOLLOW-UP:

How did their estimate and the computer compare?

Why might they differ?

How did the graphs compare with the ones they did?

TEACHER NOTES

EXPERIMENT # 3: INCREASING THE NUMBER OF BURNING CANDLES

1. PREPARATION:

   Make sure each student makes a guess about what happens, before going to the computer lab.

2. INTRODUCTION IN THE COMPUTER LAB:

   a) Remind students to choose "number of candles" program and have them enter container size of 500 mL and height of candle 20 mm.
   b) Remind students to keep a record of burn times on the sheet they have, and to answer questions on the sheet.

3. FOLLOW-UP:

   What did they learn about the effect of adding more candles?

   Why does adding candles make the flame go out sooner?

   You may want them to graph results of number of candles and compare that graph with "container-size" graph.

Appendix 2.E: List of Project Presentations

GRADE 4:

Origin of Fireworks
Volcanoes (three separate presentations on this topic)
Volcanoes and Natural Fires
Fires
Forest Fires
Great Chicago Fire
Fire Rules for Safety

GRADE 5/6:

Controls and Uses
- -ways to put out fires
- -uses among Stone Age people
- -uses among North American Indians

Careers
- -firefighters
- -parachuting firefighters
- -oil-well firefighters (Red Adair)

History of Fire
- -how early people made fire
- -Greek myths about fire

Disasters
- -Iroquois Theatre Fire in Chicago, 1903
- -Peshtigo Fire in N.W. Wisconsin, 1871
- -San Juan Hotel Fire in Puerto Rico
- -St. John's, Newfoundland, Fire

Appendix 2.F: Description of Work in Grade 4 Folders

Contents of a typical folder

Title page with a coloured drawing
Table of contents - written by students

1. Mimeo list of spelling words related to fire
2. Same words written by student & arranged in crossword pattern
3. Same words with prefixes and suffixes written by student
4. Reprint of story "Maneboza and the Sun God" from a Teacher resource book Driftwood and Dandelions
5. Mimeo question sheet on the legend from workbook above
6. Data chart from actual experiment Burning Candles
7. Worksheet from Experiment # 1
8. Graph from Experiment # 1
9. Mimeo worksheet on graphing in general
10. Student's written sentences containing the words related to fire
11. Worksheet from Experiment # 2
12. Reprint of story "Scotty's Fire" also from Driftwood and Dandelions
13. Typed sentences from story above, cut and pasted and numbered in sequence
14. Worksheet from Experiment # 3
15. More spelling words
16. Graph from Experiment # 3
17. Worksheet from "Scotty's Fire" (Yes & No Answers)
18. Worksheet from Driftwood and Dandelions - Fill in missing word
19. Worksheet from Driftwood and Dandelions - Choose a word
20. Graph for Experiment # 4 -(height of candles)
21) A list of the volcanoes found throughout the world and their
&) height in metres. Search for these numbers in a cross-word
22) type of pattern.
23) A Word Search Puzzle
&) of words related to Fire Department:
24) Find the words in a puzzle.